RAILROAD ENGINEERING

PART II

AMERICAN SCHOOL OF CORRESPONDENCE
CHICAGO ILLINOIS

RAILROAD ENGINEERING

PART II

INSTRUCTION PAPER

PREPARED BY

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U. S. A.

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PART II.

MISCELLANEOUS STRUCTURES.

99. Water Supply. The railroads of the country spent in 1910 over $13,000,000 in supplying water to their locomotives. Part of this expense is due to the fact that a bad quality of water is so injurious to a locomotive boiler (as well as rendering it difficult for the boiler to steam properly) that the added expense of procuring a suitable supply of naturally pure water or of purifying an impure supply is amply justified. A natural water supply is always more or less charged with calcium and magnesium carbonates and sulphates in addition to impurities of almost any nature which come in as the refuse from factories, etc. Some of these impurities are comparatively harmless, especially if the quantity is not large. But the evaporation of the water precipitates the calcium and magnesium, which form deposits on the surface of the boiler.

These deposits are injurious in two ways. In the first place the transfer of heat from the fire to the water is less free and there is thus a waste of energy, and in the next place the metal becomes overheated and perhaps "burned." The safety of the metal of a boiler depends on the free transfer of the intense heat of the fire to the comparatively low heat of the water or steam. The prevention of these deposits may be accomplished in one (or both) of two ways; the frequent cleaning of the boilers through the manholes and handholes provided for the purpose, and by the more or less perfect purification of the water before it enters the boiler.

The location of the water stations must be at such places and intervals as the service demands. There must always be a supply at the extremities of each division and usually at intervals of 15 to 20 miles between. Of course these intervals are varied according to the location of convenient sources of supply. The frequent

erection of municipal plants for water supply even in small places has led to the utilization of such plants, since a suitable supply for domestic use is usually satisfactory for boiler use, and since a reasonable charge to such a large consumer would generally be far less than the cost of maintaining a separate plant. In default of such supplies, a convenient intersecting stream, especially when combined with an existing but perhaps abandoned mill dam which will form a convenient storage reservoir, may be utilized. If the stream passes through a limestone region, the water may become so thoroughly impregnated with calcium compounds that a purifying plant will become a necessity and then there may arise the question of a choice between a conveniently located station with a necessary purifying plant and a less convenient location but a natural supply of purer water.

The chemical purification of water for railroad purposes has become a specialty and must be studied as such. Of course no attempt is made to produce chemically pure water as that would be unnecessarily costly. The reagents chiefly employed are quicklime and sodium carbonate. The lime precipitates the bicarbonate of lime and magnesia in the water. Sodium carbonate gives, by double decomposition in the presence of sulphate of lime, carbonate of lime, which precipitates, and soluble sulphate of soda, which is non-incrustant. The precipitates settle to the bottom of the tank and are drawn off while the purified water is drawn from the upper portion of the tank. Such purification may be accomplished for a few cents per thousand gallons. Still another method of preventing incrustation in the boiler is to introduce directly into the water tank a "non-incrustant" which, as its name implies, will so change the composition of the impurities that they will settle harmlessly and may be readily blown out.

Pumping. Except when water is obtained from a municipal water supply it must be pumped into a tank or reservoir which is usually placed with its bottom 12 to 15 feet above the rails. The pumping may be done with a wind mill, which is very cheap but unreliable, or by an ordinary steam pump operated by a boiler fed with coal, or by a gasoline engine. The last method is becoming very popular, as the pumps require but little attention and the cost of operating them has been found to be as low as one-third or even

one-fourth of the cost of steam pumping. And this is true in spite of the fact that a railroad can usually deliver slack coal or screenings at a pump house alone the line of the road at a cost that may not exceed 30 cents per ton. The cost of pumping to a track tank will usually run at from 2 cents to 6 cents per 1,000 gallons.

Tanks. The construction of the piping from a tank and even of the tanks themselves has become a specialty by manufacturing firms who can make and sell them much cheaper than may be done by any "home-made" method, and, therefore, the details of manufacture need not be here discussed. The tank must be so placed that its nearest face is about 8 feet 6 inches from the track center. When one tank is to serve several tracks or when the supply is taken from a city waterworks, a "stand-pipe" is necessary. This consists essentially of an upright pipe which stands about 14 feet above the ground where it has a horizontal arm about 7 feet long. This elbow may be turned so that the arm is either parallel or perpendicular to the track. As shown in Fig. 75, the valve mechanism is buried underground and the roof of the pit is protected so that freezing shall be obviated.

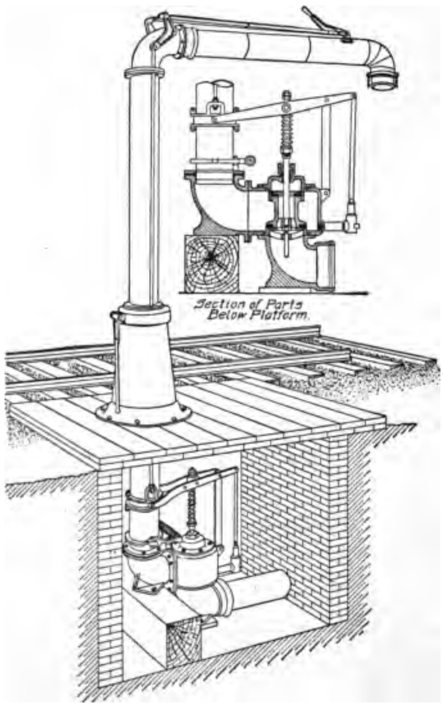

Fig. 75. Automatic Standpipe.

Track Tanks. The demands for high speed require that long runs shall be made without a stop even for water. Very long runs can only be made by taking on water while in motion from a track tank. These have a length of 1,200 to 1,500 feet and must be laid on a stretch of perfectly level track. A large item in the

expense of installing such a plant is the cost of the re-grading which is usually necessary to make the track perfectly level. On the ties and midway between the rails is a tank about 19 inches wide, 6 inches deep and as long as desired. This trough will be made of $\frac{3}{16}$-inch steel plate, stiffened and reinforced with angle bars. Such tanks can only be used by engines which are provided with a scoop on the tender which is lowered at the proper time. The high speed causes the water to rush into the scoop with such velocity that it is easily carried to the top of the leader pipe and over into the tender tank. An inclined plane at each end of the trough automatically raises the scoop and when raised it is automatically caught and held so that there is no danger that the scoop shall catch in anything on the track. To prevent the water from freezing in the winter, steam jets should be blown into the water at every 40 to 50 feet of its length. The steam required for this may be many times as great as the steam required for pumping. The cost of such an installation will be upwards of $10,000 and the annual expense about $1,500. Of course these figures will vary with the circumstances.

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If the turntable must be located on what is originally sloping ground, the masonry may need to be quite deep and heavy, since the foundation for the pivot should be especially firm. If the subsoil is not self-draining, it should be thoroughly drained by a thorough sub-drainage and the pit should be drained by a pipe leading to a suitable outfall. A turntable is usually located as an adjunct to a roundhouse, but in any case the location should be made so that the switching that must be done before and after

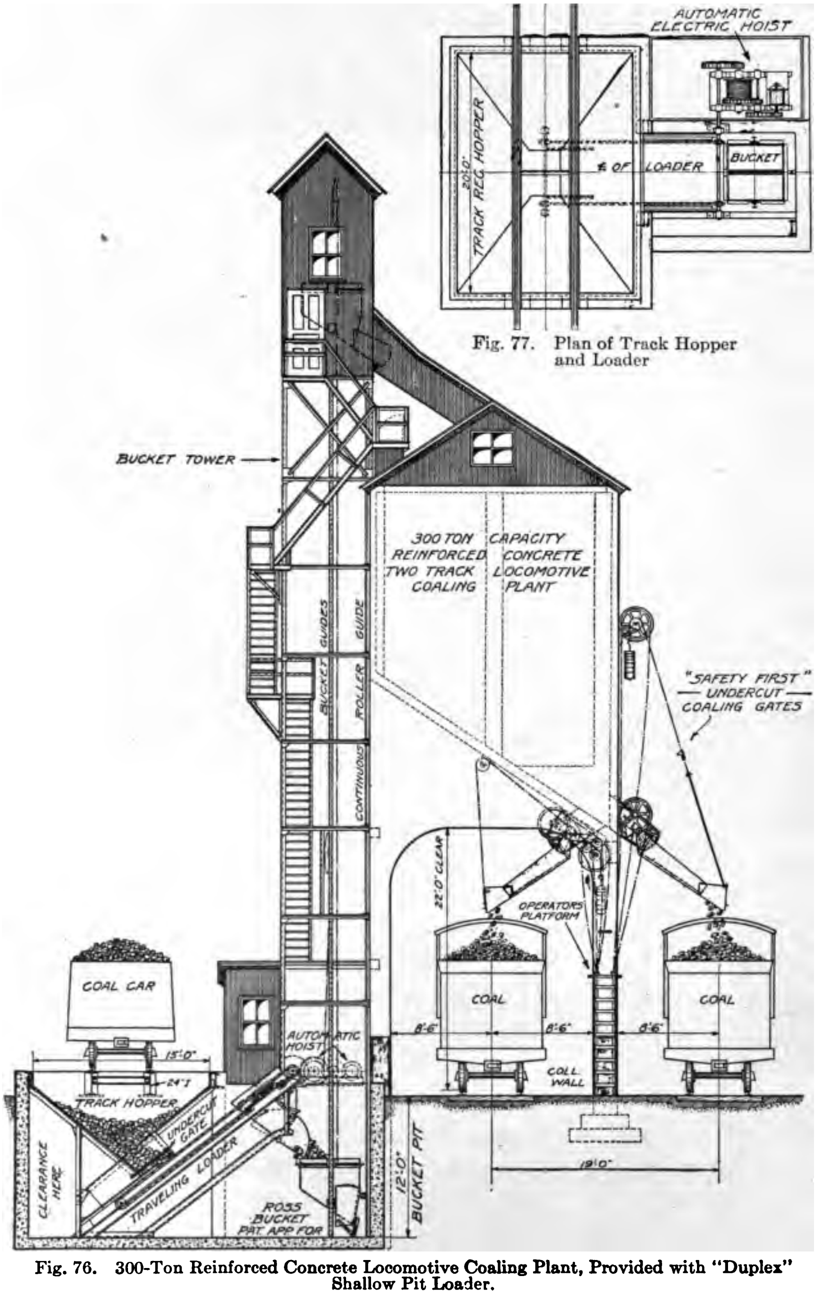

Fig. 77. Plan of Track Hopper and Loader

Fig. 76. 300-Ton Reinforced Concrete Locomotive Coaling Plant, Provided with "Duplex" Shallow Pit Loader.

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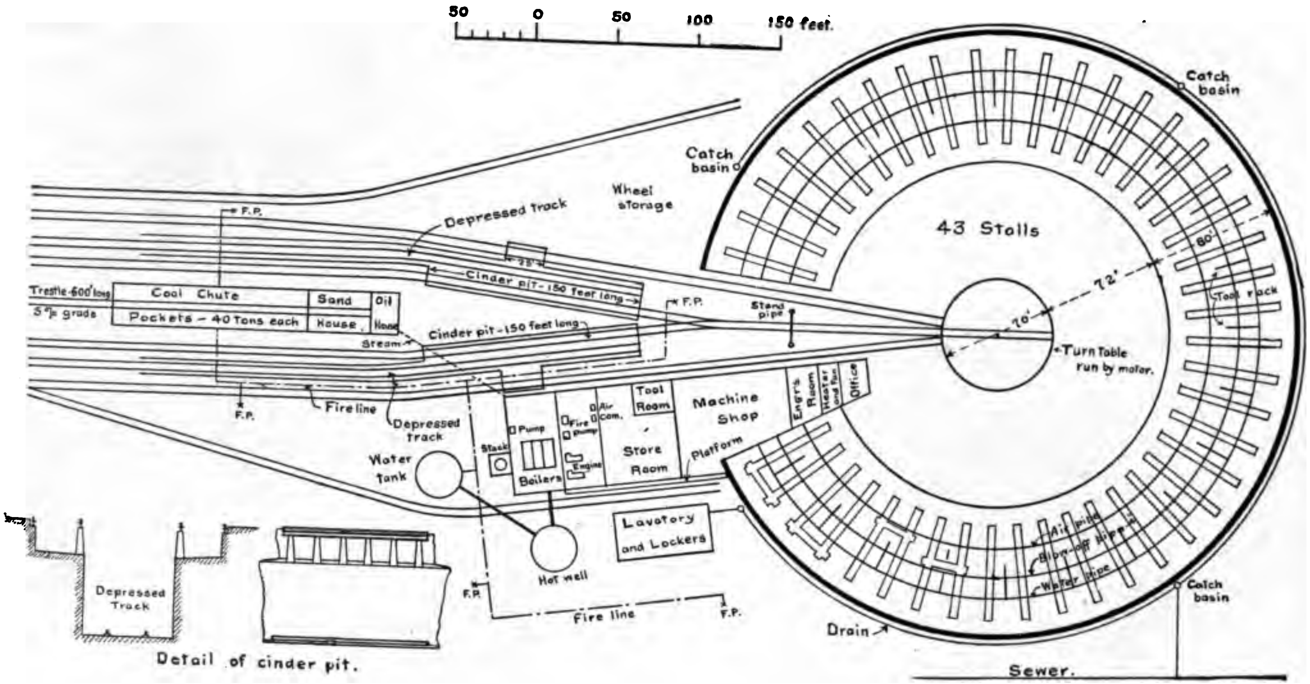

Fig. 79. Details of Typical Roundhouse.

may stray on its right-of-way requires especial precautions that cattle, straying along a highway, shall not turn into the railroad right-of-way. The fundamental idea is a structure which is not

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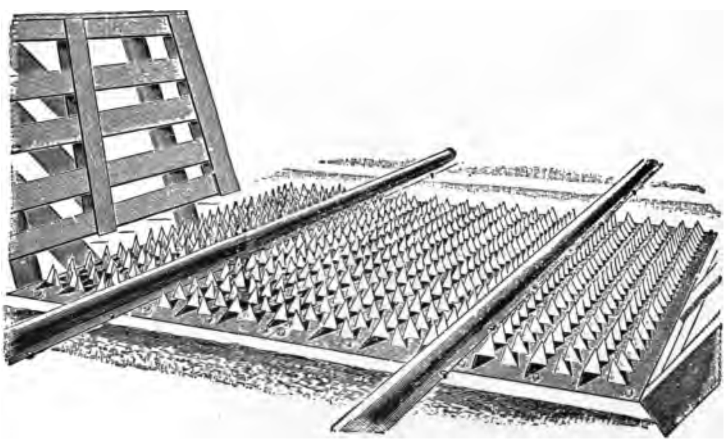

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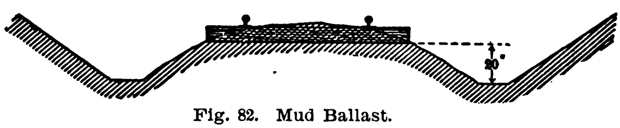

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good ballast where it occurs, but no matter how good the soil may be in some places, such a quality cannot be depended on to be continuous throughout the line or even approximately so. Considering that a heavy rain will in one day spoil the results of weeks of patient "surfacing" with mud ballast, it is seldom economical to use it if there is a gravel bed or other source of ballast anywhere

on the line of the road. If it *must* be used, then the drainage should be exceptionally perfect. The earth should be crowned over the ties in the center and the ditches on each side should be at least 20 inches below the base of the ties. This will facilitate the flow of water to the sides.

Cinders. The advantages are an almost perfect drainage, ease of handling, and cheapness, for, after the road is in operation, their use is but the utilization of a waste product. The chief disadvantage lies in the dust produced as the particles are ground up by use. Incidentally, a light traffic road would require a long time to produce enough ashes to ballast the whole road, which would imply a long period of operation with no ballast at all.

Slag. In certain places such ballast is very cheaply obtained as a waste product, it being given away for the hauling. It is free from dust and the drainage is perfect.

Shells, fine coal, etc. These are only used when their proximity makes them especially cheap. They become dusty in dry weather and correspondingly imperfect in their drainage qualities. They soon become but little better than "mud."

Gravel. A large proportion of the railroad mileage of the country is laid with gravel ballast. This is because gravel beds are so frequently found on the lines of roads, from which the gravel

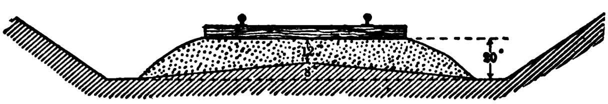

Fig. 83. Gravel Ballast.

may be dug with a steam shovel, loaded on to cars and hauled to any desired point where it is perhaps unloaded mechanically, the only strictly hand work in the whole operation being the tamping of the ballast in the track. Such methods make the cost per cubic yard very small. The gravel is easily handled and affords almost perfect drainage. If the gravel contains very fine stones or dirt, it should be screened over a half-inch screen to take the fine stuff out.

Broken Stone. This is the best form of ballast obtainable, and usually the most expensive. Although hand-broken stone is preferable, the cost of machine crushed stone is so much less that it is almost exclusively used. They should be broken so that they

will pass through a 1½-inch or 2-inch ring. It is most easily shoveled with forks, and this method has the additional advantage that the finest chips and dirt will be screened out. Such ballast holds the ties more firmly than any other form and hence is almost an essential for roads handling a great and heavy traffic at high speed. For a light traffic road running few trains and these at very moderate speed, the use of rock ballast would be almost a useless luxury unless the broken stone were very cheap and gravel were expensive or unobtainable.

Amount required. Good practice requires a depth of 12 inches of gravel or broken stone under the ties. With 6-inch × 8-inch ties spaced 24 inches between centers, the amount between the ties will be equivalent to an additional depth of about 4 inches.

Fig. 84. Broken Stone Ballast.

If the ballast has an average width of 10 feet, say 8 feet at the top and 12 feet at the bottom, then one mile of track will contain 2,607 cubic yards. Broken stone requires a little more than this since there should be a shoulder of ballast on the ends of the ties. (See Fig. 84.)

Method of laying. When ballast is laid during the original construction of the road, the proper method is to haul the most of the ballast with carts or on the contractor's temporary track and spread it evenly to the level of the bottom of the ties. Then the ties and rails can be laid and a construction train can haul whatever ballast is required for surfacing and tamping. When the ties and rails are laid on the bare subsoil and the construction trains with ballast are run over it, the rails are apt to become badly bent and kinked. A compromise between the above methods is to use light construction cars which may run on the standard gauge track without doing the injury that would be caused by standard loaded rolling stock.

Cost. The cost of ballast depends on (*a*) the initial cost as it comes to the road, (*b*) on the distance from the source of supply to the place where used, and (*c*) on the method of handling. A

little thought will show the variation in these items for different roads, and therefore any estimates of cost are necessarily approximate. As an *average* figure the cost of broken stone ballast in the track may be computed as $1.25 per cubic yard, and the cost of gravel may be put at 60 cents. The cost of placing and tamping gravel ballast is estimated at 20 to 24 cents, while the similar estimate for cinders is put at only 12 to 15 cents. The cost of loading gravel on cars, using a steam shovel, is estimated at 6 to 10 cents per cubic yard.

105. Ties. The cost of ties to a railroad is. too apt to be superficially considered as the mere market price of the ties delivered to the road. The true cost is the cost of the maintenance of suitable ties in the roadbed for an indefinite length of time. The first cost is but one item in the total cost. A cheap tie must be soon renewed. The labor of renewal is a considerable item of cost. The renewal disturbs the roadbed, which requires adjustment to keep it from getting uneven. The unavoidable unevenness of the roadbed has an actual although uncertain effect on operating expenses, increasing the fuel consumption and wear and tear on the rolling stock. It even has some effect on possible or safe speed.

In round numbers, if the cost of buying and placing a good tie is twice that of a cheap tie, and the good tie lasts twice as long as the cheap tie, the economics of the cases are nearly equal. But on the one hand we have the interest on the *extra* cost of the good tie for the lifetime of the cheaper tie and on the other hand we have the additional cost of maintenance of way when using the poorer ties and the indefinite increase of operating expenses due to a poor roadbed. The annual cost of a system of ties should therefore be considered as the sum of (*a*) the interest on the first cost, (*b*) the annual sinking fund that would buy a new tie at the end of its life, and (*c*) the average annual maintenance for the life of the tie, which includes the cost of laying and the considerable amount of subsequent tamping that must be done until the tie is settled in the roadbed, besides the regular track work due to the tie. Such a method of comparison is essential in considering the economics of chemically treated ties and untreated ties.

Wood. A good tie must last as long as possible in the ground, must be hard enough not to be unduly affected by "rail-cutting,"

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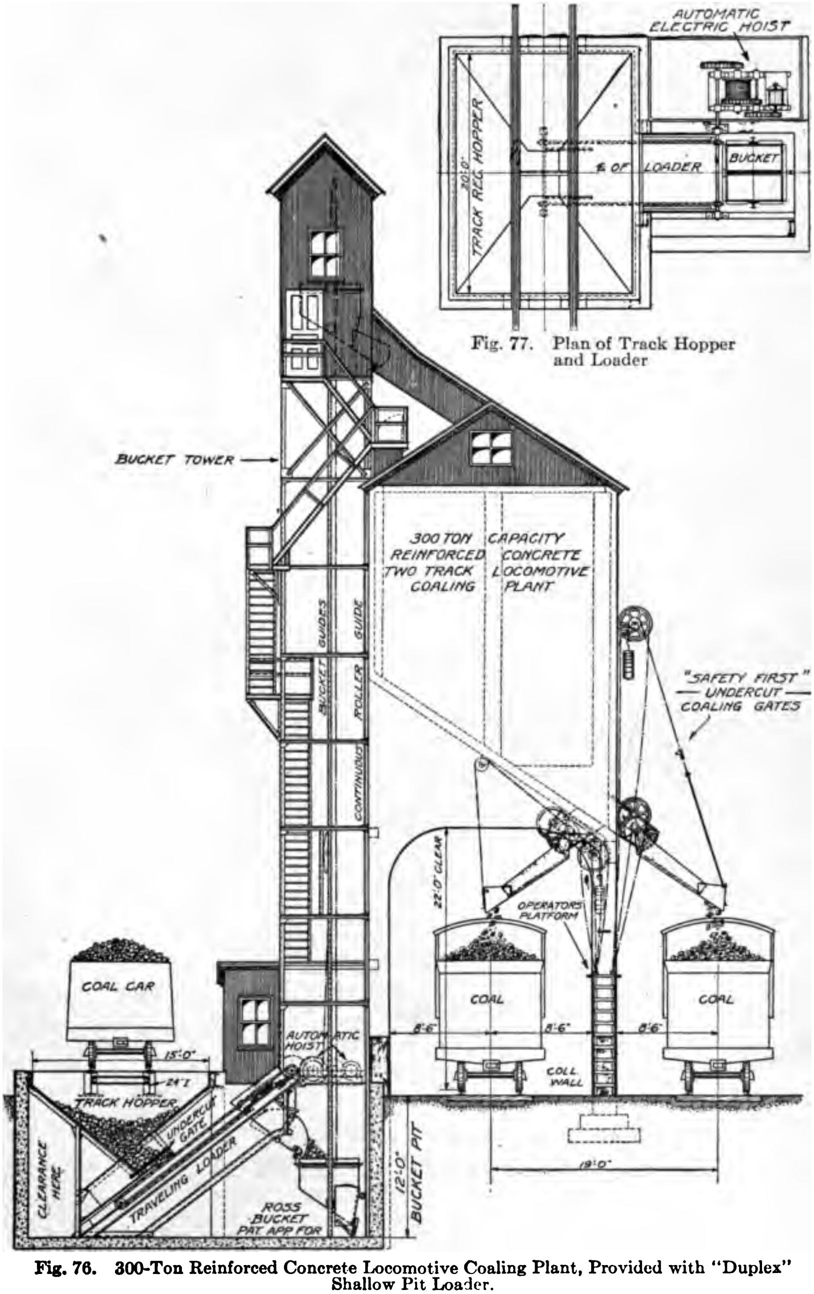

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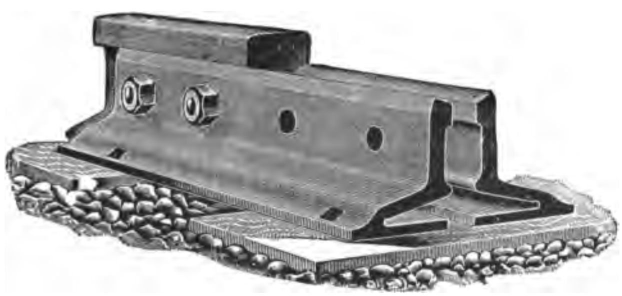
It can readily be proved that if all sizes of rails had exactly similar cross-sections (which is nearly true) then the stiffness of a rail varies as the *square* of the weight and the strength varies as the $\frac{3}{2}$ power. This means that if we add 10 per cent to the weight (and therefore to the cost) of the rail we are adding 21 per cent to the stiffness, and over 15 per cent to the strength. As a more concrete example, suppose that some desire to make the weight of the rail for a road 60 lb. per yard, and others wish to use a 70-lb. rail. At $30 per ton (of 2,240 pounds) the *difference* of cost will be $471.42 per mile of single track. But on the other hand, although the cost is increased by $16\frac{2}{3}$ per cent, the strength is increased 26 per cent, and the stiffness is increased 36 per cent. The increase in stiffness is more than double the increase in cost. Unfortunately there is no absolute criterion as to the amount of stiffness or strength required since it depends largely on the unknown, uncertain and variable tamping of the ties and the support which the ties receive from the ballast. But the above *relative* figures hold good, and considering that a stiff track means decreased rolling resistance, higher

Fig. 90. Bonzano Rail Joint.



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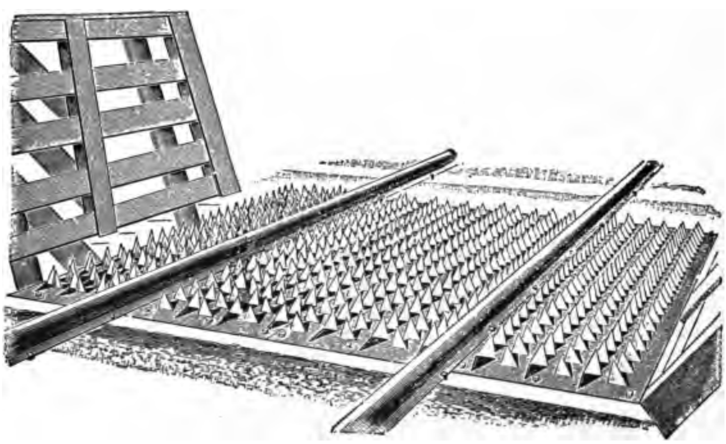

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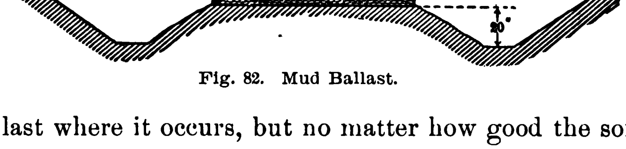


Fig. 82. Mud Ballast.

good ballast where it occurs, but no matter how good the soil may be in some places, such a quality cannot be depended on to be continuous throughout the line or even approximately so. Considering that a heavy rain will in one day spoil the results of weeks of patient "surfacing" with mud ballast, it is seldom economical to use it if there is a gravel bed or other source of ballast anywhere

on the line of the road. If it *must* be used, then the drainage should be exceptionally perfect. The earth should be crowned over the ties in the center and the ditches on each side should be at least 20 inches below the base of the ties. This will facilitate the flow of water to the sides.

Cinders. The advantages are an almost perfect drainage, ease of handling, and cheapness, for, after the road is in operation, their use is but the utilization of a waste product. The chief disadvantage lies in the dust produced as the particles are ground up by use. Incidentally, a light traffic road would require a long time to produce enough ashes to ballast the whole road, which would imply a long period of operation with no ballast at all.

Slag. In certain places such ballast is very cheaply obtained as a waste product, it being given away for the hauling. It is free from dust and the drainage is perfect.

Shells, fine coal, etc. These are only used when their proximity makes them especially cheap. They become dusty in dry weather and correspondingly imperfect in their drainage qualities. They soon become but little better than "mud."

Gravel. A large proportion of the railroad mileage of the country is laid with gravel ballast. This is because gravel beds are so frequently found on the lines of roads, from which the gravel

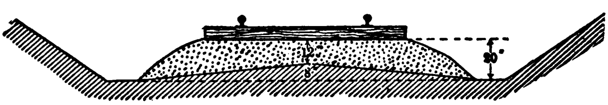


Fig. 83. Gravel Ballast.

may be dug with a steam shovel, loaded on to cars and hauled to any desired point where it is perhaps unloaded mechanically, the only strictly hand work in the whole operation being the tamping of the ballast in the track. Such methods make the cost per cubic yard very small. The gravel is easily handled and affords almost perfect drainage. If the gravel contains very fine stones or dirt, it should be screened over a half-inch screen to take the fine stuff out.

Broken Stone. This is the best form of ballast obtainable, and usually the most expensive. Although hand-broken stone is preferable, the cost of machine crushed stone is so much less that it is almost exclusively used. They should be broken so that they

lateral motion. Note that the flanges on the lower side of the plate not only stiffen it and make it much stronger structurally but they also secure the plate to the tie and prevent an objectionable rattling. The very presence of these flanges, however, requires that the plates shall be pressed or hammered on to the tie until the flanges penetrate to their full depth. This may be done with a heavy maul but it is best done by utilizing the hammer of a pile driver.

Fig. 96. Wolhaupter Tie Plate.

Notwithstanding the popularity of flanged tie plates, several up-to-date roads are using only tie plates with flat bottoms, claiming that the punctures made by the flanges hasten decay or crushing under the plate, which is avoided with flat plates. A flat plate, designed for use with screw spikes (note the round holes) is shown in Fig. 97.

109. Rail Braces. The pressure against the outer rail on a curve, and also the pressure against the inner rail when a train stops on a curve which has a considerable superelevation, is frequently provided for by "rail braces" such as are illustrated in Figs. 99 and 100. Sometimes these are made of cast iron, but these are brittle and are apt to be broken by a blow from a spike maul when the spikes are driven.

Fig. 97. Economy No. 9 RW

The preferable form, although it is more expensive, is to forge them or "press" them from wrought iron or steel. In Fig. 100 is shown a form which has a plate which runs under the rail which thus makes it a combined rail brace and tie plate.

110. Spikes. The fundamental requirement of a spike is holding power, but it must also be cheap, easily applied, and easily removed when necessary. It has been found that mak-

ing the surface rough and even jagged, decreases rather than increases the holding power, and also destroys the fibre of the wood. The best form is a spike with plane and smooth faces. The point should be made so as to *cut* the fibres of the

Fig. 98. Atlas Tie Plate.

wood instead of crushing them. By this means the fibres are pressed outward and downward, and thus any upward pull only tends to draw the fibres back to their original place and so increase the pressure against the spike and thus increase the friction and the holding power. The standard spike for rails weighing more than

Fig. 99. Atlas Brace KK.

Fig. 100. Atlas Brace K.

56 pounds per yard is $5\frac{1}{2}$ inches long and $\frac{9}{16}$-inch square. There will be about 375 in a keg of 200 pounds. On this basis, if the ties are 24 inches apart and four are used per tie, there will be required 5,632 spikes per mile or 28.16 kegs. Of course a consider-

able allowance must be made for loss and waste of various kinds.

111. Track Bolts. The track bolt must have sufficient strength to hold the angle plates together with such force as will develop the full strength of the angle plates. And yet this must be accomplished so that the friction developed will not be so great that the rails may not slide in the joints during temperature changes. On a straight track the contractive pull due to a fall of temperature is so great that no possible gripping of the bolts could prevent slipping, but it is quite possible that when rails expand, and especially when on a curve, the resistance to slipping might be so great that the track would bulge out of alignment instead of slipping at the joints. Such an effect does actually take place when the allowance for expansion is insufficient and the rails continue to expand after they have butted end to end.

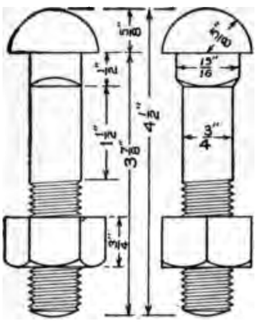


Fig. 101. Track Bolts.

Another requirement is that the bolts shall not turn while the nut is being turned. This is accomplished by an enlargement of the bolt just under the head, as shown in Fig. 101. This fits fairly closely in a corresponding oval-shaped hole in the angle plate. The sizes shown in the figure are about what should be used with a 70 or 80-pound rail. Heavier rails require a longer bolt and one that is proportionately heavier. The type of rail joint used, and also the type of nut lock if any, will determine the required length of bolt, while the weight of rail should determine the diameter. The diameters vary from $\frac{3}{4}$ inch to 1 inch, and the lengths from 3 inches to 5 inches.

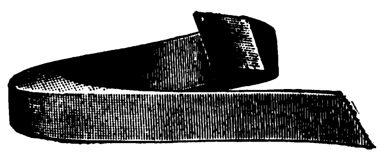


Fig. 102. Ajax Tail Washer.

112. Nut Locks. There are three types of nut lock—(*a*) those which have an elastic cushion under the nut which absorbs the vibrations that would otherwise loosen the nut, (*b*) those by which the nut is made to grip the bolt (by some unusual device) so that vibration will be insufficient to loosen it, and (*c*) the "positive" type, in which the locks are pre-

vented from turning by some definite and positive mechanical check.

The "Ajax Tail Washer," shown in Fig. 102, is a sample of the first class, although it also has some of the elements of the third class, since the sharp steel points will tend to bite into both the under side of the nut and the side of the angle plate where it rests whenever there is a tendency for the nut to turn backward. These points merely drag and slip when the nut is being tightened.

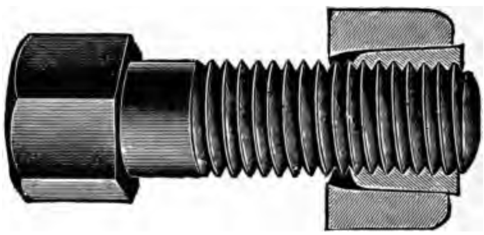


Fig. 103. Columbia Nut Lock.

The Columbia nut lock, shown in Fig. 103, is a sample of the second class. The nut is compound, the inner piece being a four-sided frustum of a pyramid, the edges being rounded. This fits into a corresponding recess in the outer piece. The inner piece is also cut through so that it may be slightly squeezed together. The pyramidal form requires both pieces to turn together. When the outer piece comes in contact with the angle plate it is forced back (relatively to the inner piece) which squeezes

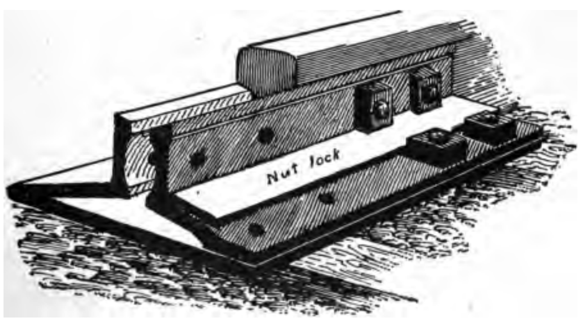


Fig. 104. Gordon Nut Lock.

the inner piece together and causes it to grip the bolt. The more the nut is turned, the tighter the grip.

The Gordon nut lock, shown in Fig. 104, is a sample of the third class, although it is designed to be used only with the form of angle plate which is shown. In the form shown the square

nuts must be turned until one edge is exactly on line. A one-eighth turn forward or back will always accomplish this. Thus when the bar is slipped in all nuts are absolutely prevented from turning. The above designs have been selected as mere samples of each class from a great multitude of designs of greater or less merit which are on the market.

LAYING TRACK.

113. Surveying. After the earthwork is completed and the culverts and bridges are built, the center line of the track must be re-located on the roadbed surface of the fills and cuts. Reference points should have been established during the original survey so that by the intersection of two radii swung from permanently established points the beginnings and endings of all curves may be re-located. Then all intermediate stations should be filled in. A line of levels should then be run and the agreement of these

RIGHT. WRONG.

Fig. 105. Right and Wrong Method of Laying Ties.

levels with the designed grade should be determined. If the levels of the cuts and fills has been followed with sufficient closeness during construction, there should be no discrepancy except that the levels of fills should be somewhat higher than that called for so as to allow for subsequent settlement.

114. Laying Ballast. This has already been discussed in §104, as has also the policy of laying the ties and rails first and then drawing the ballast in a construction train on the poorly supported track.

115. Laying Ties. If the ties have been sawed to an exact length, the alignment of one end will of course line up the other but when ties have been hewed and chopped off and sometimes even when they have been sawed, there is a range of several inches in their length and then it is required that they shall be aligned at one end or the other. A little stick may be furnished the track-

men as a spacer, but with a little experience they will space the ties as closely to the required spacing as is necessary. The ties should always be laid with rings convex upward rather than concave. Of course a pole tie, when it is perfectly symmetrical, will be the same either way, but there is usually a choice, as is shown by the figure. When the rings are concave upward there is a greater chance for water to soak in and cause decay. Turning the tie the other way, the water will shed off more freely.

116. Laying Rails. Rails should be laid so that the joints are staggered as nearly as possible. This requires a half-rail length at the start. But the difference of length of the outer and inner rails of a curve will disturb the arrangement of the joints, no matter how perfectly it may start. These differences may be neutralized by selecting rails which are a foot or two shorter than the usual length. But the occurrence of a switch will require a readjustment of the joints, and may require a rail cutting so as to bring a joint where desired. Very short lengths of rail should be avoided. If a full length rail comes a few feet short of a point where a joint *must* be made, it should be cut so that both pieces shall have a fair length. The rails are first laid approximately in position and end to end.

When placing the joints on the rails, allowance must be made for rail expansion due to temperature. The theoretical amount to be allowed is .0000065 of the length for each degree Fahrenheit. If it could be readily determined just what is the temperature of the rail (which is possibly much higher than that of the air) at the time the rail is laid and also the highest and lowest temperature that it will ever attain, the problem would be comparatively simple, but the fact that these quantities are so uncertain seem to render useless any attempt at an exact calculation and to justify the rough and ready rule of "allowing $\frac{5}{16}$ inch for coldest weather, $\frac{1}{8}$-inch during the spring and fall, and $\frac{1}{16}$-inch during the very hottest weather." The allowance of $\frac{1}{16}$-inch during the very hottest weather is apparently based on the idea that the rails should never be allowed to butt up against each other, for then any additional expansion will cause the rails to buckle. If a rail was laid when its actual temperature was 60° F., its length of 33 feet would be increased by about $\frac{1}{8}$ inch if its temperature were raised to

120°, as might readily happen under a burning summer sun when the temperature of the air in the shade was perhaps 100°. A practical method of making an allowance which would be sufficiently accurate would be as follows: Place a bulb thermometer (one without a metal frame) so that the bulb lies against the rail and then cover it up so as to protect it from the air and so that it will assume the temperature of the rail as closely as possible. The expansion of a 33-foot rail for each degree is

$$.0000065 \times 33 \times 12 = .002574 \text{ inch.}$$

If we allow 120° (some allow 150°) as the maximum beyond which it is assumed that the temperature will never rise, then the difference between this maximum and the ascertained temperature of the rail, when multiplied by the above allowance per degree, equals the gap to be allowed at each joint. Strips of sheet metal of the required thickness should be furnished to the trackmen. These strips are placed temporarily between the rail ends which obviates any necessity for measuring on their part. When the joints have been bolted up, one line of rails is spiked so that they are at the proper distance from the ends of the ties. Then by using a "track gauge" at every other tie the other line of rails may be spiked down. The intermediate ties are then spiked. "Standard" gauge, which is in almost universal use in this country, is 4 feet $8\frac{1}{2}$ inches = 4.708 feet. Although the gauging should be all right for these other ties, the gauge should be at hand to check the previous work, especially if it is on a sharp curve. Track instructions frequently specify that rails should be previously bent before laying around curves, or in other words, that the rails should have the proper curve when lying freely on the ties. Of course the necessity for this increases with the degree of curvature, it being unnecessary for very easy curves.

The practical trouble comes at the joints; the rails instead of having a common tangent will intersect at an angle which is destructive both to the track and the rolling stock when trains are run at high speed. The ideal method is to have the rail bending done by rollers in a rolling mill and this method is almost a necessity for the very sharp curvature employed on some electric roads. The field method is to use a "rail bender" which bends the rail in

lengths of about two feet and which must be operated very carefully and skilfully to avoid ruining the rail. A rail is bent until, when a string is stretched from the inside of the head at one end to the inside of the head at the other end, the distance from the middle point of the string to the inside of the head at the middle of the rail is as computed below:

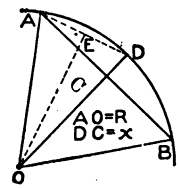


Fig. 106.

In Fig. 106, since the triangles AOE and ADC are similar, AO : AE :: AD : DC, or $R = \frac{1}{2} AD^2 \div x$. When as is usual, the arc is very short compared with the radius, $AD = \frac{1}{2} AB$ very nearly. Making this substitution, we have

$$R = \frac{\text{chord}^2}{8x} \text{ (very nearly)} \qquad \textbf{(54)}$$

Inverting the formula we have the formula required for present use:

$$x = \frac{\text{chord}^2}{8R} \text{ (very nearly)} \qquad \textbf{(55)}$$

Although not mathematically accurate, the maximum error in any practical case is far within the attainable accuracy using a string.

Example. What should be the middle ordinate for the outer rail (33 feet long) for a 6 degree curve? We will call the chord 33 feet since the slight inaccuracy involved only tends to neutralize the inaccuracy of the formula. $R = 955.37 + 2.35 = 957.72$. Then 33^2 (which equals 1089) divided by $(8 \times 957.72) = .142$ foot or 1.70 inches. If a similar calculation is made for the inside rail the difference in the ordinate is less than .01 inch, which shows that unless the curvature is excessively sharp there is no need to make the allowance for half-gauge (2.35, as is done above) nor even to use great accuracy in the decimals. A table giving the middle ordinates for 33-foot rails for different degrees of curvature is a desirable part of the equipment of each track foreman.

The spikes on the opposite sides of a rail should be driven "staggering," so that there will be less tendency to split the tie. The direction of the staggering should be reversed at the two ends of the tie, so as to prevent a loosening of the hold of the spikes,

such as would occur if the reverse method were used and the tie were to become displaced and not perpendicular to the rails. Such an item of construction, while very simple, is of vital importance.

117. Surfacing. Track centers (stakes) having been placed in line, the alignment of the track is made perfect. The rail laying should have been done with the rails a few inches below their proper grade. Then jacks are placed under the ties (or rails, as most convenient) and the track is raised to grade, as given by grade stakes which should have been previously set. Using tamping picks or shovels, the ballast is jammed under the ties until they are solid at the desired grade. Picks or tamping bars are best for tamping broken stone ballast, but gravel can be most easily tamped with shovels.

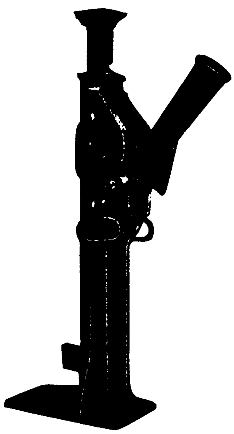


Fig. 107. Trip Ballast Gang Jack.

118. Super-elevation of the Outer Rail on Curves. It is one of the demonstrations of physics that the force required to make a mass move in a circular path equals $Gv^2 \div gR$, in which G is the weight, v the velocity in feet per second, g the acceleration of the force of gravity in feet per second in a second, and R the radius of curvature. If the rails on a curve were level transversely, such a force could only be furnished by the pressure of the wheel flanges against the rail. To avoid this objectionable pressure, the outer rail is elevated until the inward component of the inclined wheel pressure equals the computed centripetal force required.

In Fig. 108, *ob* may represent the resultant pressure on the rails at the same scale at which *oc* represents the weight G. Then *ao* is the required centripetal force. From similar triangles, we may write $sn : sm :: ao : oc$. Call $g = 32.17$. Call $R = 5730 \div D$, which is sufficiently accurate for the purpose. Call $v = 5280V \div 3600$, in which V is the velocity in miles per hour. *mn* is the distance between rail centers, which for an 80-lb. rail and standard gauge is 4.916 feet; *sm* is slightly less than this. As an average value, call it 4.900, which is its exact value when the super-elevation is $4\frac{3}{4}$ inches. Calling $sn = e$, we have

$$e = sm\,\frac{ao}{oc} = 4.9\,\frac{Gv^2}{gR}\,\frac{1}{G} = \frac{4.9 \times 5280^2 V^2 D}{32.17 \times 3600^2 \times 5730}$$

$$e = .0000572 V^2 D \qquad \textbf{(56)}$$

Studying the above formula, it will first be noticed that the required super-elevation varies as the *square* of the velocity, which means that a change of velocity of only 10 per cent would require a change of super-elevation of 21 per cent. Since train velocities over any road are so very variable, it shows that it is impossible to make any super-elevation fit all trains even approximately. There are several approximations in the above formula, but none of them will affect the result as much as a change of less than one per cent in the velocity.

Practical Rules. A very simple and commonly used rule is to elevate one inch for each degree of curvature. This rule agrees with the above formula when the velocity is about 38 miles per hour. If a train is running slower than the speed for which the super-elevation was designed, the practical effect is to relieve the pressure against the outer rail which still exists in spite of super-elevation on account of the necessity of turning the groups of four or six wheels under a truck or engine. Therefore the better plan is to elevate for the fastest trains. Thirty-eight miles an hour is so near the maximum for a light traffic branch line, that the above rule is very fair, although, of course, not so good as a more accurate one.

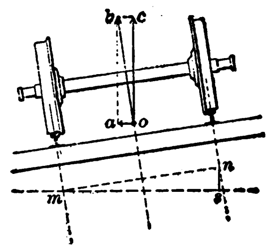


Fig. 108.

Another rule, which is especially good for track maintenance when the track foreman may not even know the degree of curve, is developed as follows: Assume that x in equation 55 is equal to e in equation 56, and we have

$$\frac{chord^2}{8R} = .0000572\ V^2D$$

but since $D = 5730 \div R$, we have

$$chord^2 = 2.621\ V^2 \text{ and}$$

$$chord = 1.62\ V \qquad \textbf{(57)}$$

Assume that the limit of 50 miles per hour is set as the speed of the fastest trains, then *chord* = 1.62 × 50 = 81 feet. This means that if a string or tape, having a length of 81 feet, is stretched between two points at that distance apart on the inner head of the outer rail, the length of the ordinate at the middle of the string equals the required super-elevation for 50 miles per hour. Similar computations can be made and tabulated for all other desired speeds. On double track, since the speed on an ascending grade will almost certainly be less than the speed of trains coming down that grade, there should theoretically be a difference in the super-elevation to allow for this difference of speed. On some roads the track instructions contain specific instructions to allow for this.

SWITCHES AND TURNOUTS.

119. Switch Construction. The universal method of keeping the wheels of railroad rolling stock on the rails is to put

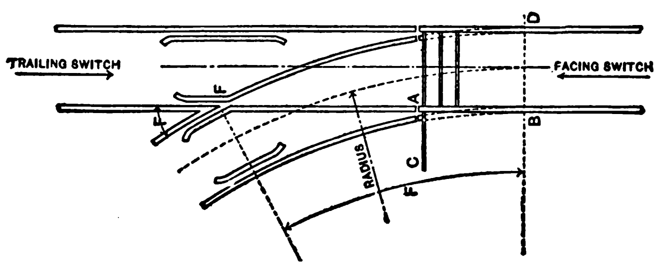


Fig. 109. Stub Switch.

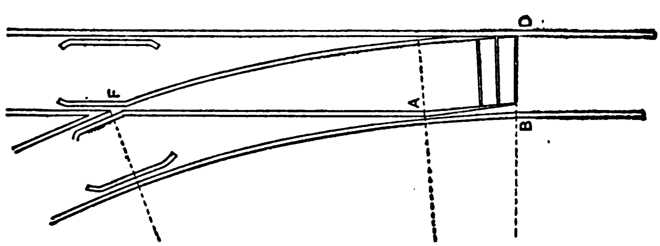


Fig. 110. Point Switch.

flanges on the inner edges of the wheels. When the wheels are to be led away from the main track, it must be done by creating a new pathway for these flanges. This is done by leading the wheel flanges *through* the rails or by raising the wheels sufficiently so

that they may pass *over* the rails. Both methods will be described. The method of leading the flanges through the rails is most commonly used since it does not require *raising* the rolling stock over the rail.

When the rails are first led out from the main track, it must be done by one of two general methods, the stub-switch method, illustrated in Fig. 109, or by the point-switch method, illustrated in Fig. 110. Of course these figures are only diagrammatic and it should be at once understood that in these figures as well as in many others in this chapter, it has been necessary to use very short radii, very wide gauge, and very large frog angles in order

Fig. 111. Details of Point Switch.

to illustrate the principles by figures which are suitable for the page and which would at the same time be intelligible.

The use of the stub switches is now confined to the cheapest of yard work or private switches which run off from sidings. They should never be used in any main track. Their construction may be implied from Fig. 109. The pair of movable rails are tied together at the proper gauge by tie rods. The two pairs of stub ends are of course fixed. The details of a point switch are illustrated in Fig. 111. Note that one rail on each side is absolutely unbroken. The other rail has nearly all of the head cut away and a part of one flange. The other flange and the web, with that part of the head immediately over the web still remains. The tie rods which are clearly shown connect this pared-down rail with a

similar rail on the other side. The last tie rod has an extension to which the switch rod from the switch stand is attached. The moving rail slides on tie plates which have rail braces on the outer ends which stiffen the rail against the unusual lateral strain to which it is subjected. The angle of these switch points varies from 0° 52′ to 2° 36′.

Switch Stands. One type of switch stand, which also combines a semaphore (or signal which shows its position) is shown in

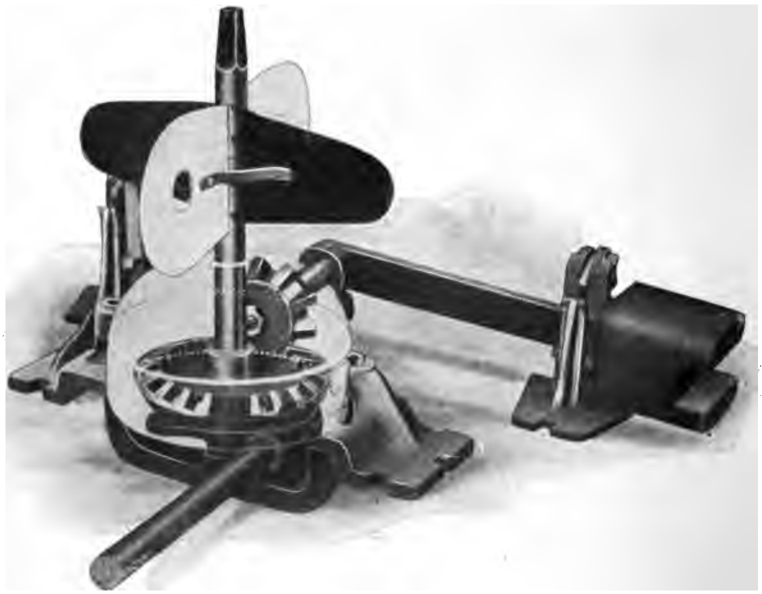


Fig. 112. Switch Stand.

Fig. 112. The mechanism is of course covered, the cover being indicated by the faint lines. The type shown is but one of a multitude for which there is no space here.

Guard Rails. These are shown opposite the frogs in both Figs. 109 and 110. They obviate any danger of the wheel running on the wrong side of the frog point and also save the frog point from excessive wear. The flange-way space between the heads of the guard rail and the wheel rail must therefore not exceed a definite quantity, which is made about two inches. Since this is less than the distance between the heads of two ordinary sized rails when placed base to base, to say nothing of any space

for spikes, the base of the guard rail must be cut away somewhat. These guard rails are made from 10 to 15 feet long and are bent a few feet from each end so that there shall be no danger that a wheel flange shall strike the ends.

Frogs. When the outer switch rail reaches the opposite main rail, the wheel flange must either pass *through* the head of the main rail or the wheel must be raised so that the flange may pass over the rail. The most commonly used frogs are those of the type of which the wheel flange passes through the head of the rail. The geometrical outline of such a frog is shown in Fig. 113.

The frog *number* may be found by dividing the distance from the "point" to any chosen place by the width of the frog at that place, or in the figure $ch \div ab$. But since c is the imaginary intersection of the sides produced and is not easily determinable with accuracy on the frog, it is sometimes easier to measure the

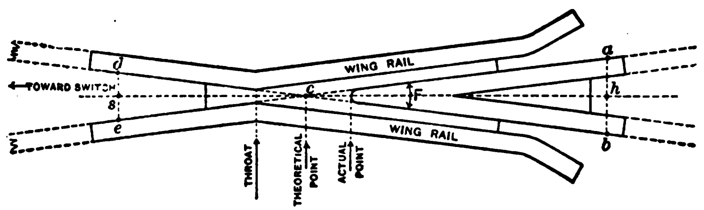
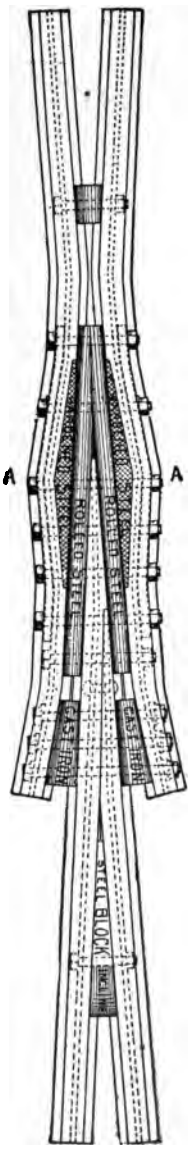


Fig. 113. Diagram of Frog.

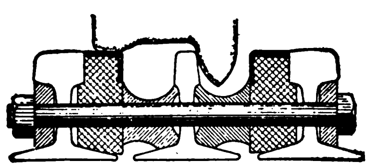
width at two places (*ed* and *ab*) and then divide the sum of those widths by the total distance *sh*; this will give the same result as before. This measuring may be done with any convenient unit of length such as a pencil or a spike. Find the place where the width of the frog just equals the unit of length and then step off that distance to the "point." The fundamental objection to all frogs of this type is that they make a break in the main rail which causes a jar when a train is run over the frog at high speed. If the frog is made "stiff" as is illustrated in Fig. 114, the track has the advantage of being literally *stiff*, but the wheels have to run over the gap. The design shown in the figure aims to obviate any drop of the wheel at any point and this will be fairly accomplished as long as the hardened steel faces can resist the wear which is very severe in the older and commoner designs.

The "spring-rail" frog, illustrated in Fig. 115, is an attempt to obviate the gap for main line trains. Wheel flanges running on to the switch force back a portion of the main track rail which is normally held in place by a heavy spring. Running on to the switch is supposed to be done at comparatively slow speed, which permits the rail to be forced back without danger of derailment. But since the main rail is kept in place by the pressure of a spring, the frog lacks the stiffness of a "stiff" frog. The method of raising the wheel and carrying it over the main rail is illustrated in Fig. 116, which shows one of the many devices to accomplish this end. The method has the very positive advantage of leaving the main track absolutely unbroken.



In Fig. 117 is shown a method of avoiding a break even at the switch. The switch rails are at the level of the main rails at the switch point but gradually rise higher until the wheel flange is high enough to cross over the main rail. Such a switch must be operated at slow speed.

120. Mathematical Design. In all of the following demonstrations, the track lines represent the gauge lines or the lines of the inside head of the rails. The older formulæ, which are still in extensive use on account of their simplicity, all assume that the switch rails are bent to arcs of simple curves extending from the switch point to the frog, and that they are tangent to



SECTION A-A

Fig. 114. Anvil-face Frog.

the main rails at the switch point. On account of its common use and also because it forms a fitting introduction to the more

exact method, it will be given. In all of the following demonstrations, the following notation will, for simplicity, be kept uniform. R will represent the radius of curvature of the main track, if it is curved, and r is the radius of the switch rails. F will always represent the frog angle, and g the gauge of the track. L will represent the "lead" or the distance measured on the main track from the switch point B to the frog point F.

The angle FOD in Fig. 118 equals the angle F, and BD is the versed sine of F to the radius FO. From this relation we may derive the equation

$$r + \frac{1}{2}g = \frac{g}{\text{vers F}} \quad (58)$$

also, since BF ÷ BD = $\cot\frac{1}{2}$F, BD = g and BF = L, we have

$$\text{L} = g \cot\frac{1}{2}\text{F} \quad (59)$$

Also,

$$\text{L} = \left(r + \frac{1}{2}g\right) \sin \text{F} \quad (60)$$

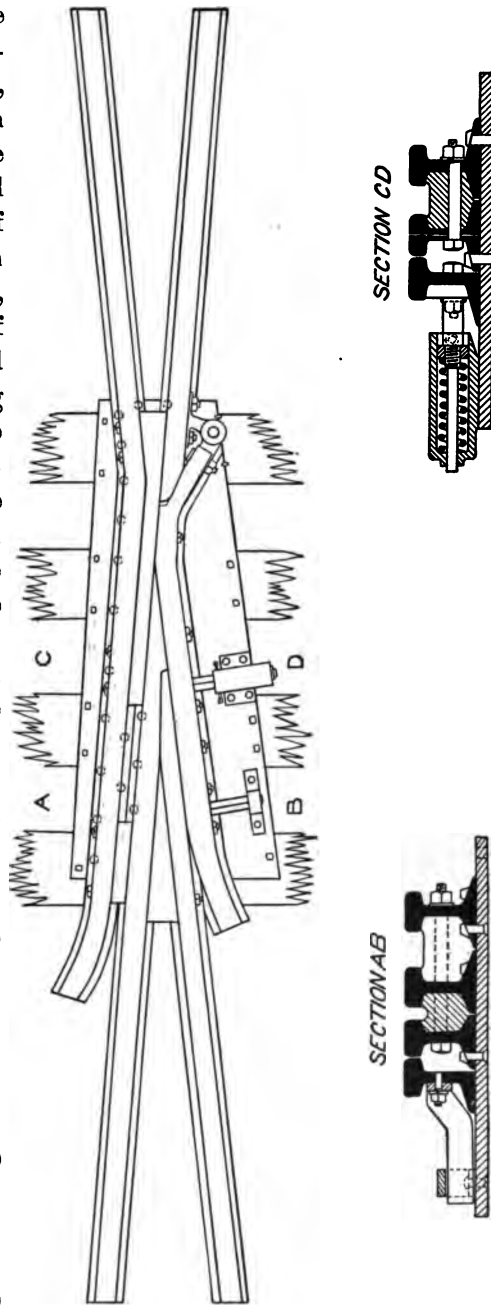


Fig. 115. Spring-rail Frog.

and $$QT = 2r \sin \frac{1}{2} F \qquad \textbf{(61)}$$

All of the above formulæ involve the angle F. Reference to Table III* will show that with one chance exception the values of F are always odd and the accurate computation of their trigonometrical functions is tedious. Fig. 119 shows that the ratio of the length to width of a frog, or $pc \div ab$, which is called n, is also equal to $\frac{1}{2} \cot \frac{1}{2} F$. This relation can be used to derive the following marvellously simple formulæ:

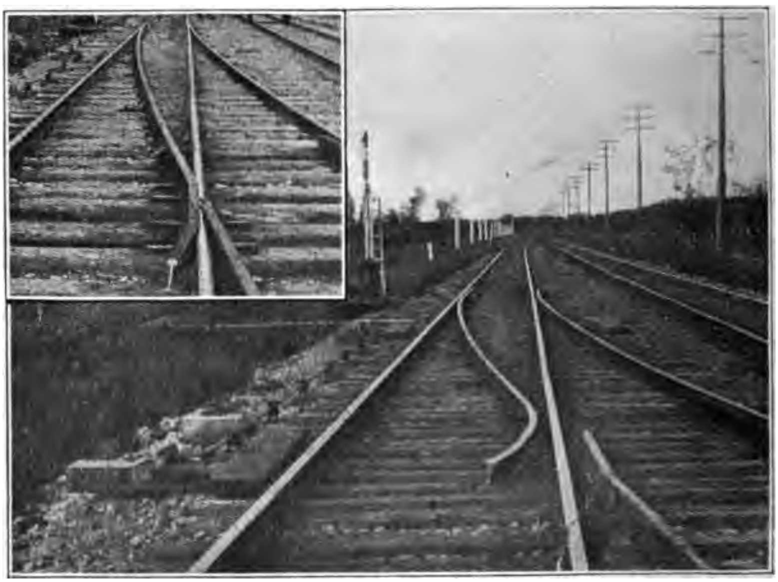


Fig. 116.

Since $L = g \cot \frac{1}{2} F$, and $n = \frac{1}{2} \cot \frac{1}{2} F$, we may at once derive the equation

$$L = 2gn \qquad \textbf{(62)}$$

But in Fig. 120 the line QZ, drawn midway between the rails, bisects DF at Z and also, since DQ is one-half of DB, QZ is one-half of BF or $= \frac{1}{2} L$. $OQ = r$ and the angle $ZOQ = \frac{1}{2} F$.

*See Webb's "Trigonometric Tables," published by American School of Correspondence, Chicago, Ill. Price, 50c.

Then $r \div \frac{1}{2}L = \cot\frac{1}{2}F$, from which

$$r = nL \tag{63}$$

Combining equations 61 and 62, we have

$$r = 2gn^2 \tag{64}$$

The above relations only lack the merit of correctness of application to make the whole subject very simple. They were first devised when stub switches were in universal use and although

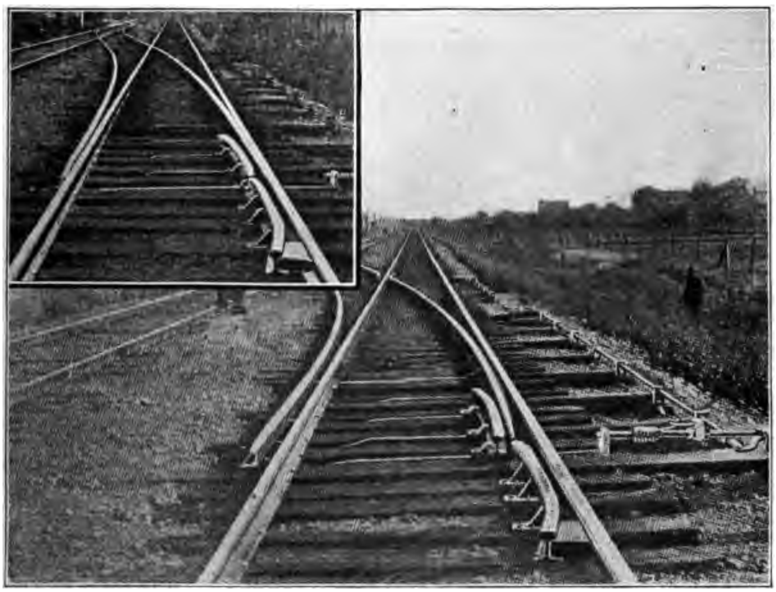


Fig. 117.

it is theoretically possible to make a stub switch conform to these lines, it is impracticable even there. But with point switches, which are in almost universal use, the switch rail makes an angle varying from 0° 52′ to 2° 36′ with the main rail. The frog rails are also made straight.

The effect of each of these changes, taken separately, is to shorten the lead. The combined effect is to shorten the lead from 15 to 25 per cent. In Fig. 121, DM represents the straight point rail and HF the straight frog rail, the two being connected by the

arc MH, tangent to both. The central angle of this arc is therefore $(F - a)$, a being the angle (MDN) of the point rail. The chord MH makes an angle with the main rails which equals

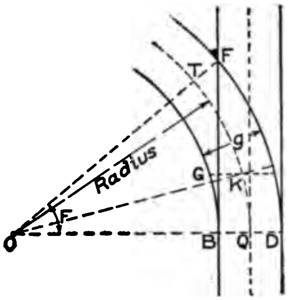


Fig. 118.

$$\frac{1}{2}(F - a) + a = \frac{1}{2}(F + a)$$

Call FH $= f$ and MN $= k$. Then HM sin $\frac{1}{2}(F + a) = g - f \sin F - k$. But HM $= (r + \frac{1}{2}g)\ 2 \sin \frac{1}{2}(F - a)$. Substituting this value of HM in the previous equation and solving for $(r + \frac{1}{2}g)$ we have

$$(r + \frac{1}{2}g) = \frac{g - f \sin F - k}{2 \sin \frac{1}{2}(F + a) \sin \frac{1}{2}(F - a)}$$

$$= \frac{g - f \sin F - k}{\cos a - \cos F} \qquad \textbf{(65)}$$

$$ST = 2r \sin \frac{1}{2}(F - a) \qquad \textbf{(66)}$$

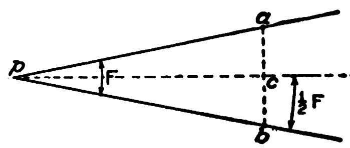


Fig. 119

The lead BF $= L =$ HM $\cos \frac{1}{2}(F + a) + f \cos F +$ DN

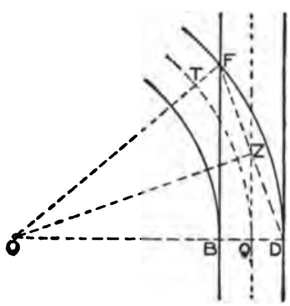


Fig. 120.

$$= (g - f \sin F - k) \cot \frac{1}{2}(F + a) + f \cos F + DN \qquad \textbf{(67)}$$

If $(r + \frac{1}{2}g)$ has already been computed numerically from equation 65, it will be more simple to compute L as follows:

$$L = 2(r + \frac{1}{2}g) \sin \frac{1}{2}(F - a) \cos \frac{1}{2}(F + a) + f \cos F + DN$$

$$= (r + \frac{1}{2}g)(\sin F - \sin a) + f \cos F + DN \qquad \textbf{(68)}$$

If the lead is computed for a turnout from a straight track using a No. 9 frog, a straight point rail and frog rail of the dimensions given in the middle section of Table III*, it will be found that the lead becomes 72.61 instead of 84.75, the corresponding dimension assuming that the lead rails were circular throughout. Table III* was computed on the basis of the above equations and the point switch dimensions which are in general use. The two references to section numbers in the table are to sections in Webb's "Railroad Construction," from which the tables were taken.

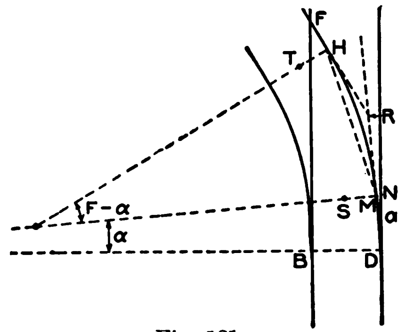


Fig. 121.

121. Turnout from the Outer Side of a Curved Track. When it is attempted to compute the dimensions of a turnout, from a curved track on the basis of using straight point rails and straight frog rails, it not only renders the demonstration exceedingly complicated, but it would involve assumptions regarding the mechanical construction which probably would not be followed in practice. Therefore the following demonstration is given with the purpose of showing the effect on the

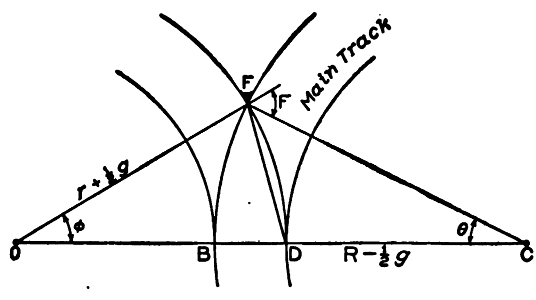


Fig. 122.

switch dimensions of curving the main track, the switch rails being circular throughout, and then drawing a reasonable inference as to the dimensions which should be followed for point switches from a curved main track. In the triangle FCD, in Fig. 122, we have

*See Webb's "Trigonometric Tables," published by American School of Correspondence, Chicago, Ill. Price, 50c.

$$(FC+CD) : (FC-CD) :: \tan\frac{1}{2}(FDC+DFC) : \tan\frac{1}{2}(FDC-DFC);$$

but $\frac{1}{2}(FDC+DFC) = 90° - \frac{1}{2}\theta$, and $\frac{1}{2}(FDC - DFC) = \frac{1}{2}F$;

also $FC+CD=2R$ and $FC-CD=g$;

$$\therefore\ 2R : g :: \cot\frac{1}{2}\theta : \tan\frac{1}{2}F$$

$$:: \cot\frac{1}{2}F : \tan\frac{1}{2}\theta$$

$$\therefore\ \tan\frac{1}{2}\theta = \frac{gn}{R} \qquad (69)$$

Also, $OF : FC :: \sin\theta : \sin\phi$; but $\phi = (F - \theta)$

then $$r + \frac{1}{2}g = \left(R + \frac{1}{2}g\right)\frac{\sin\theta}{\sin(F-\theta)} \qquad (70)$$

The lead, $$BF = L = 2\left(R + \frac{1}{2}g\right)\sin\frac{1}{2}\theta \qquad (71)$$

A study of the three equations above will show that as the curvature of the main track increases and R grows less, tan θ increases and θ increases. Then $(F - \theta)$ decreases and r increases. When $\theta = F$, as it readily may, $(F - \theta) = 0$ and r becomes infinity, that is, the switch rails become straight. If θ becomes greater than F, sin $(F - \theta)$ becomes negative and r becomes negative. The interpretation of this is that the center of the switch track will be on the same side as the center of the main track. The figure will then correspond with Fig. 123 except that the positions of O and C and also of ϕ and θ will be transposed and also that "main track" should read "side track." Equations 73 and 75 will be the same as before, but equation 74 will be changed to

$$\left(r - \frac{1}{2}g\right) = \left(R + \frac{1}{2}g\right)\frac{\sin\theta}{\sin(\theta - F)} \qquad (72)$$

If we call d the degree of curve corresponding to the radius r, D the degree of curve corresponding to the radius R, and d' the degree of curve of a turnout from a straight track for the same frog angle F, it will be found that $d = d' - D$ very nearly. It

will also be found that the "lead" as computed above and as computed for a straight track will agree to within a few inches and frequently to within a fraction of an inch.

Example. Compute from the above equations the values of L and r (and then of d) for the cases when the main track has a 4° degree curve and when it has a 10° curve; solve them for number 6, 9 and 12 frogs. This makes six cases. Compare them with values computed by the approximate rule.

In all these cases it may be shown that the discrepancies are very small. If such calculations are made for very sharp curves and for very large frog angles (which must be considered as bad practice), the discrepancies would be considerable, but since such turnouts (if ever made) should be operated at very slow speeds, the errors would have but little practical importance. Therefore we are justified in applying the approximate rule for turnouts from a curved track—use the same "lead" as for straight track; the degree of curvature for the switch rails to the *outside* of the main track will be the *difference* of the degree of curve for the main track and the tabular value for the degree of curve of the switch rails; for a turnout to the *inside* of a curved main track it may be similarly shown that the proper degree of curve for the switch rails is the *sum* of the degrees for the main track and the tabular value for the switch rails from a straight track.

Also, since it may be shown that the effect of using straight point rails and straight frog rails is to shorten the lead and to lessen the radius in approximately the same proportion, it may be assumed without material error that we may apply the same rule as above, and instead of taking the values of "lead" and "degree of curve" for the switch rails from the tabular form which uses circular switch rails throughout, we may take them from the revised form using straight switch rails and straight frog rails and apply the same rule.

122. Turnout from the Inner Side of a Curved Track. By the formation of precisely similar equations as were used in the previous section, we may derive the equation

$$\tan\frac{1}{2}\theta = \frac{gn}{R} \qquad (73)$$

From the triangle OFC we may derive

OF : FC :: sin θ : sin (F + θ), from which

$$\left(r + \frac{1}{2} g\right) = \left(R - \frac{1}{2} g\right) \frac{\sin \theta}{\sin (F + \theta)} \quad (74)$$

$$\text{The lead BF} = L = 2 \left(R - \frac{1}{2} g\right) \sin \frac{1}{2} \theta \quad (75)$$

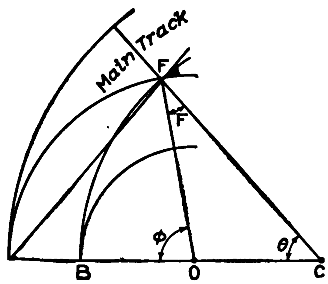


Fig. 123.

The details of the solution of the above equations should be worked out by the student; also a numerical demonstration of the fact, already referred to, that the degree of the turnout (d) is very nearly the *sum* of the degree of the main track (D) and the degree (d') of a turnout from a straight track when the frog angle is the same. It will be found that the discrepancy in these cases is somewhat larger than in the previous case, although it is still so small that it may be neglected when the curvature of the main track is small. An inspection of the figure will show that when the curvature of the main track is sharp the curvature of the turnout is very excessive. Such conditions should be avoided if possible, that is, a turnout should not be located on the inside of a very sharply curved main track if it can be avoided.

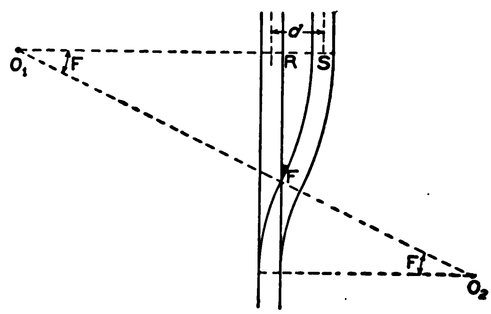


Fig. 124.

123. Numerical Examples. 1. Determine the lead and the radius of curvature for a turnout to the outside of a 4° 30′ curve using a No. 8 frog and a point switch.

2. Determine the lead and the radius of a curvature for a turnout to the inside of a 3° 40′ curve using a No. 7 frog and point switch.

In each of the above examples use the switch point angles, length of switch point and length of straight frog rails as given in Table III*.

124. Connecting Curve from a Straight Track. The "connecting curve" is that part of the siding between the frog and the point where the siding becomes parallel with the main track, or the distance FS in Fig. 124. Call d the distance between track centers. The angle FO_1R must equal the angle F. If we call r' the radius of the connecting curve, we may say

$$\left(r' - \frac{1}{2}g\right) = \frac{d-g}{\text{vers F}} \qquad (76)$$

$$\text{FR} = \left(r' - \frac{1}{2}g\right)\sin \text{F} \qquad (77)$$

The distance FR may be shortened somewhat by the method indicated in Fig. 129. Theoretical accuracy would apparently require that we should consider a short length of straight track at the point F. The effect may readily be shown to shorten the radius r' and to shorten the distance FR by an amount exactly equal to the length of the straight frog rail, but in actual track laying such a procedure might be considered a useless refinement. And therefore in this case as well as in the succeeding similar cases, the effect of the straight frog rail will be ignored. It should likewise be noted that the figure has been drawn for simplicity as if the switch rails were circular. But since the point O_2 has no connection with the demonstration, it is immaterial what is the form of the switch rails back of F. This same remark applies to the following similar demonstrations.

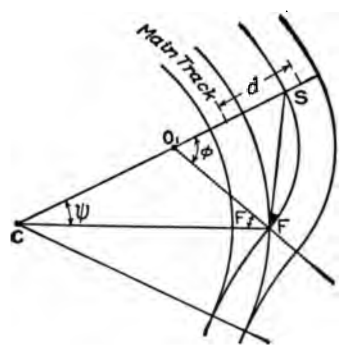


Fig. 125.

125. Connecting Curve from a Curved Track to the Outside. As in the previous case the only required quantities are the radius r of the connecting curve from F to S, Fig. 125, which

*See Webb's "Trigonometric Tables," published by American School of Correspondence, Chicago, Ill. Price, 50c.

must be determined from r and the angle ϕ ($= F + \psi$). From the triangle CSF we may write

$$CS + CF : CS - CF :: \tan\frac{1}{2}(CFS + CSF) : \tan\frac{1}{2}(CFS - CSF)$$

but $\frac{1}{2}(CFS + CSF) = 90° - \frac{1}{2}\psi$; and since the triangle O_1SF is isosceles, $\frac{1}{2}(CFS - CSF) = \frac{1}{2}F$.

$$\therefore 2R + d : d - g :: \cot\frac{1}{2}\psi : \tan\frac{1}{2}F$$

$$:: \cot\frac{1}{2}F : \tan\frac{1}{2}\psi \qquad \text{from which}$$

$$\tan\frac{1}{2}\Psi = \frac{2n(d-g)}{2R+d} \qquad \textbf{(78)}$$

From the triangle CO_1F we may derive

$$r - \frac{1}{2}g : R + \frac{1}{2}g :: \sin\Psi : \sin(F + \Psi)$$

$$\therefore r - \frac{1}{2}g = \left(R + \frac{1}{2}g\right)\frac{\sin\Psi}{\sin(F+\Psi)} \qquad \textbf{(79)}$$

Also $$FS = 2\left(r - \frac{1}{2}g\right)\sin\frac{1}{2}(F + \Psi) \qquad \textbf{(80)}$$

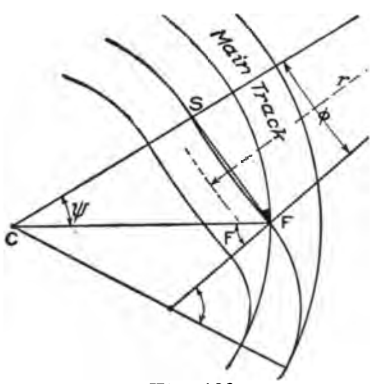


Fig. 126.

126. Connecting Curve from a Curved Track to the Inside. There are three solutions according as F is greater than, equal to, or less than Ψ. In the first case, we may readily deduce, as in the previous section, from the triangle CFS (see Fig. 126) that

$$(2R - d) : (d - g) :: \cot\frac{1}{2}\Psi : \tan\frac{1}{2}F$$

and finally that

$$\tan\frac{1}{2}\Psi = \frac{2n(d-g)}{2R-d} \qquad \textbf{(81)}$$

And as before, in equations 78 and 79, we may derive

$$\left(r - \frac{1}{2}g\right) = \left(R - \frac{1}{2}g\right)\frac{\sin \psi}{\sin (F - \psi)} \qquad (82)$$

and $$FS = 2\left(r - \frac{1}{2}g\right)\sin \frac{1}{2}(F - \psi) \qquad (83)$$

When $\psi = F$, equation 80 will become

$$\tan \frac{1}{2} F = \frac{1}{2n} = \frac{2n(d-g)}{2R - d}$$ from which we may derive

$$2R - d = 4n^2 (d - g) \qquad (84)$$

This equation gives the value of R which makes this condition possible. If we make $F = \Psi$ in equations 81 and 82, we find in the first case that r is infinite, which means that the track is straight, and in the second case that FS = infinity times zero, which is "indeterminate." But from the figure itself we may readily see that

$$FS = \left(R - \frac{1}{2}g\right)\sin \Psi \qquad (85)$$

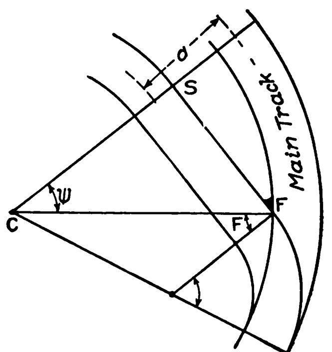


Fig. 127.

When $F < \Psi$ we may derive the value of $\tan \frac{1}{2}\Psi$ to be the the same algebraically as in equation 81, although the figure is so different. By the same method as before we may derive for the value of r the equation.

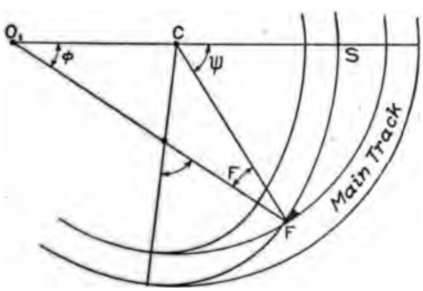


Fig. 128.

$$r + \frac{1}{2}g = \left(R - \frac{1}{2}g\right)\frac{\sin \Psi}{\sin (\Psi - F)} \qquad (86)$$

Also $$FS = 2\left(r + \frac{1}{2}g\right)\sin \frac{1}{2}(\Psi - F) \qquad (87)$$

127. Crossover Between Two Parallel Straight Tracks. As in the previous cases, although the figures are drawn for simplicity with switch rails as simple curves, the demonstrations only involve the frog angles and the nature of the track beyond the frog. The better method is that shown by the full lines, when the track is straight between the frogs. But this consumes so much of the main track (many times what is indicated in the distorted figure) that a reversed curve (as is indicated by the dotted curves) may be used. The length of the straight crossover track is F_1T.

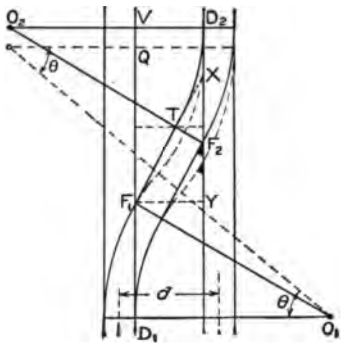


Fig. 129.

$$F_1T \sin F_1 + g \cos F_1 = d - g$$

$$F_1T = \frac{d - g}{\sin F_1} - g \cot F_1 \qquad \textbf{(88)}$$

The total distance along the track is

$$DV = D_1F_1 + YF_2 + F_2D_2 = D_1F_1 + XY - YF_2 + F_2D_2$$

but $\qquad XY = (d - g) \cot F_1$ and $XF_2 = g \div \sin F_2$

$$\therefore DV = D_1F_1 + (d - g) \cot F_1 - \frac{g}{\sin F_2} + D_2F_2 \qquad \textbf{(89)}$$

If a reversed curve with equal frogs is used, we will have the construction as is indicated by the dotted lines, and we have

$$\text{vers } \theta = \frac{d}{2r} \qquad \textbf{(90)}$$

also

$$DQ = 2r \sin \theta \qquad \textbf{(91)}$$

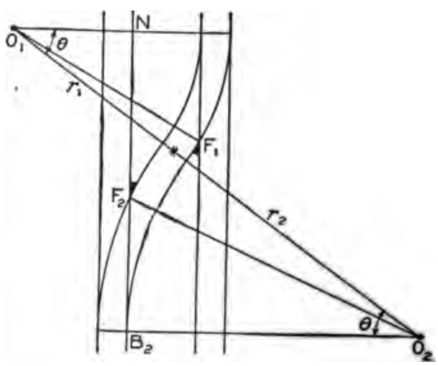


Fig. 130.

If it should for any reason be necessary to use frogs of different sizes, it may be done, but the point of reversed curve, instead

of being in the exact center, will be as is indicated in Fig. 130. In this case we will have

$$r_2 \text{ vers } \theta + r_1 \text{ vers } \theta = d$$

$$\therefore \text{ vers } \theta = \frac{d}{r_1 + r_2} \qquad \textbf{(92)}$$

The distance along the track will depend, as before, on the length of the "lead" for each switch. If it were circular, as indicated in the figure, we would have

$$B_2N = (r_1 + r_2) \sin \theta \qquad \textbf{(93)}$$

but the true lead for point switches would be less than this by the difference between the true L and $(r + \frac{1}{2} g) \sin F$. Therefore, this correction should be computed and subtracted for each switch.

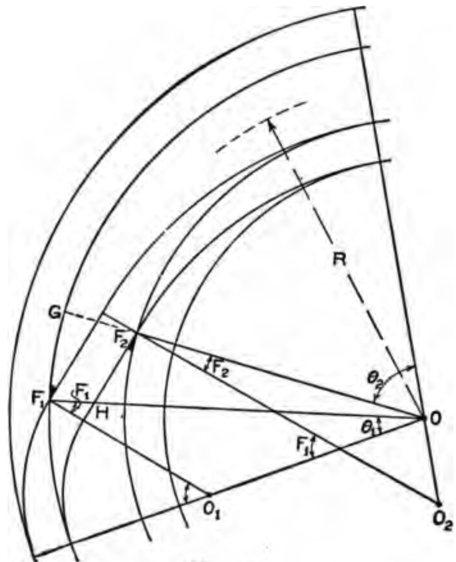


Fig. 131.

128. Crossover Between Two Parallel Curved Tracks. In the previous case there is no practical limitation as to frog numbers, but in this case there are limitations on what frogs are per-

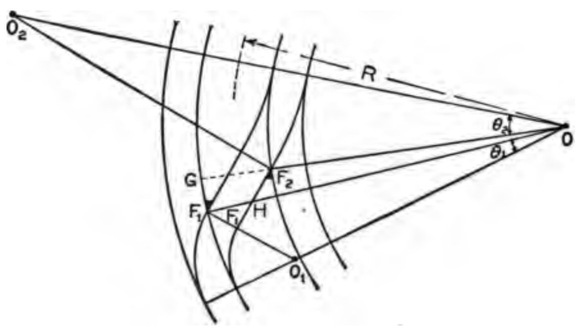


Fig. 132.

missible. If the connecting track is straight, there are still three cases depending on the value of F_2, as in section 121. Two of these cases are illustrated in Figs. 131 and 132. The following

demonstrations apply to both figures. If one frog (F_1) is chosen, then F_2 becomes determined as a function of F_1. If F_1 is the angle for some even frog number, F_2 will in general be an angle that does not correspond to any even frog number and therefore will need to be made to order. If F_1 is less than some limit, depending on the width (d) between the parallel tracks, it will be impossible to have a straight connecting track, and at some other limitation it will be impossible to have the reversed curve connecting track shown later. In Figs. 131 and 132 assume F_1 as known. Then $F_1H = g \sec F_1$. In the triangle HOF_2 we have

$$\sin HF_2O : \sin F_2HO :: HO : F_2O$$

but $\sin F_2HO = \cos F_1$; $HF_2O = 90° + F_2$; $\sin HF_2O = \cos F_2$;

$$HO = R + \frac{1}{2}d - \frac{1}{2}g - g \sec F_1; \quad F_2O = R - \frac{1}{2}d + \frac{1}{2}g$$

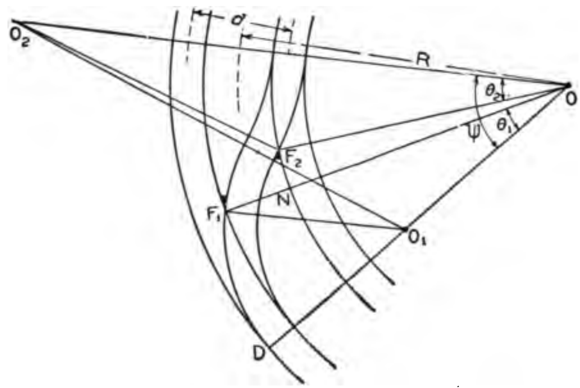


Fig. 133.

$$\therefore \cos F_2 = \cos F_1 \frac{R + \frac{1}{2}d - \frac{1}{2}g - g \sec F_1}{R - \frac{1}{2}d + \frac{1}{2}g} \qquad \textbf{(94)}$$

Knowing F_2, θ_2 is determinable from equation 69. To determine the relative position of the frogs F_1 and F_2,

$$HOF_2 = 180° - (90° - F_1) - (90° + F_2) = F_1 - F_2; \text{ then}$$

$$GF_1 = 2\left(R + \frac{1}{2}d - \frac{1}{2}g\right) \sin \frac{1}{2}(F_1 - F_2) \qquad \textbf{(95)}$$

If the connecting curve is made a reversed curve, as is shown in Fig. 133, the frogs F_1 and F_2 may be chosen at pleasure (within rather close limitations, however), and this will usually permit the adoption of regular standard sizes and will not necessitate the making to order of special sizes. We may then consider that F_1 and F_2 are known and that they are equal or unequal as desired. Employing formula 29 in Table XXX,* we may write:

$$\text{vers } \Psi = \frac{2\,(S - OO_2)\,(S - OO_1)}{(OO_2)\,(OO_1)}$$

in which
$$S = \frac{1}{2}\,(OO_1 + OO_2 + O_1\,O_2)$$

but
$$OO_1 = R + \frac{1}{2}\,d - r_1$$

$$OO_2 = R - \frac{1}{2}\,d + r_2$$

$$O_1\,O_2 = r_1 + r_2$$

$$\therefore S = \frac{1}{2}\,(2R + 2r_2) = R + r_2$$

$$S - OO_2 = R + r_2 - R + \frac{1}{2}\,d - r_2 = \frac{1}{2}\,d;$$

$$S - OO_1 = R + r_2 - R - \frac{1}{2}\,d + r_1 = r_1 + r_2 - \frac{1}{2}\,d;$$

$$\therefore \text{vers } \Psi = \frac{d\,(r_1 + r_2 - \frac{1}{2}\,d)}{(R - \frac{1}{2}\,d + r_2)\,(R + \frac{1}{2}\,d - r_1)} \qquad (96)$$

$$\sin OO_2\,O_1 = \sin \Psi\,\frac{OO_1}{O_1\,O_2} = \sin \quad \frac{R + \frac{1}{2}\,d - r_1}{r_1 + r_2} \qquad (97)$$

$$O_2\,O_1\,D = \Psi + O_1\,O_2\,O \qquad (98)$$

$$NF_2 = 2\,(R - \frac{1}{2}\,d + \frac{1}{2}\,g)\,\sin\frac{1}{2}\,(\Psi - \theta_1 - \theta_2) \qquad (99)$$

The chief advantages of the above method are that it not only permits the use of standard size frogs, but also uses up less of the main track between the extreme switch points.

* Found in Webb's "Railroad Construction".

129. Problems in Switch Computation. 1. A siding runs off from a straight main track, using a No. 8.5 frog. The distance between track centers is 13 feet. What is the radius of the connecting curve and its length?

2. A siding using a No. 9 frog runs off from the outside of a 4° 30′ curve. What is the radius and length of the connecting curve? In all of these problems, consider the distance between track centers to be 13 feet.

3. Using the same frog, a siding is to run to the inside of the same track. What will be the radius and length of the connecting curve? Until Ψ is computed, it is impossible to say which of the three possible cases will be used, but the solution of equation 80 immediately decides that point, which will show that Ψ is slightly greater than F, but that the difference is so little that the resulting value r is very great. $\frac{1}{2}(\Psi - F)$ is such a small angle that Table VI* must be used to determine its sine.

4. If a crossover is to be run between two straight parallel main tracks 13 feet between centers, using No. 8 frogs, how much will be saved in distance measured along the main track by using a reversed curve rather than a straight track? Since the *difference* in distance is called for, we may ignore in this solution the absolute length of the switch rails and consider that they would be the same in either case.

5. Required the dimensions for a cross-over between two main tracks which are on a 4° 30′ curve; the distance between track centers thirteen feet, the frog for the outer main track (F_1 in Fig. 132) is No. 9; F_2 is No. 7; the connecting curve is to be a reversed curve. When the radius of a double main track is given, it means the radius of the center line between the two tracks. We must, therefore (as indicated in Fig. 133), add and subtract 6.5 to the radius of a 4° 30′ curve (1273.6) to obtain the radii of the centers of the two main tracks. The figure and formulæ allow for this. Since point switches would unquestionably be used, we must determine r_1 and r_2 by the method outlined in §121; R_1 the radius of the outer main track = 1280.1 (which means that D_1 = 4° 29′), while R_2 the radius of the inner track = 1267.1 and D_2 = 4° 31′. Then by the rule of §121, r_1 = radius of $(d_1 + D_1)°$ curve

*See Webb's "Trigonometric Tables," published by American School of Correspond-, Chicago, Ill. Price, 50c.

= radius of ($7° 31' + 4° 29'$) curve = 478.34; r_2 = radius of $(d_2 - D_2)°$ curve = radius of ($12° 26' - 4° 31'$) curve = 724.31. d_1 and d_2 are the degrees of curve given in the first section of Table III* as being suitable for a No. 9 and a No. 7 frog on a straight track. Obtain θ_1 and θ_2 by substitution in equations 69 and 73. It will be found that the point of reversed curve comes but a fraction of an inch from the frog point F_2. If the computations had apparently indicated that the point of reversed curve would come beyond either frog point (or between either frog and its switch), it would have shown the impracticability of the use of a No. 7 and a No. 9 frog under these particular conditions. It shows that in this case the limit was practically reached.

6. Solve the same problem using a No. 9 frog in both cases. In this case it will be found that the total length of main track between the extreme switch points will be somewhat increased, but that the point of reversed curve will be nearly midway between the two tracks, as is preferable. A comparison of the two solutions will then show how close are the limitations in the choice of frogs to be used.

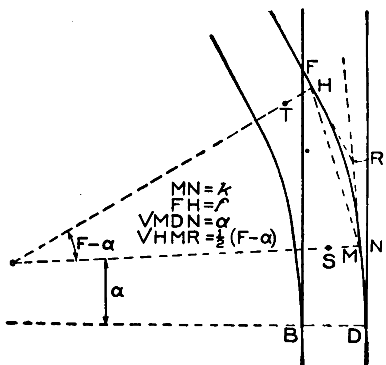


Fig. 134.

130. Practical Rules for Switch Laying. The following directions are based on the methods previously given for allowing for the effect of straight point rails and straight frog rails when used from a curved main track. When the position of the switch block is definitely determined, then there is no choice but to cut the main rails wherever the location calls for, but as the main track rail would be merely bent out to form the outer switch rail, there need be no rail cutting near the switch point, except that a rail-joint in the main rail should not come at or near the switch point. The frog has a length of from six to nine feet. A movement one way or the other of less than ten or twelve feet will bring one end of the frog at an existing joint and thus save one rail cutting.

*See Webb's "Trigonometric Tables," published by American School of Correspondence, Chicago, Ill. Price, 50c.

After having definitely determined just where the switch is to be located, mark on the rails the points B, D and F in Fig. 134. Measure off the length of the switch rails DN, and locate the point M at the distance k from N. If the frog must be placed during the brief period between the running times of trains it will be easier to joint up to the frog a piece of rail at one or both ends of just such a length that they may be quickly substituted for an equal length of rail taken out of the track. When the frog is thus in place, the point H becomes located. The curve between M and H is a curve of known radius. Substituting in equation 54 the value of *chord* and R, we obtain x, or db in Fig. 135, which is the ordinate for the middle point of the curve. Then $a''a$ and $c''c$ will be three-fourths of db. Theoretically this will give a parabolic curve, but the difference will not be appreciable. Having located and spiked down the rail HM, the opposite rail may be easily put in at the proper gauge.

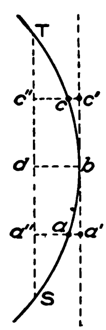
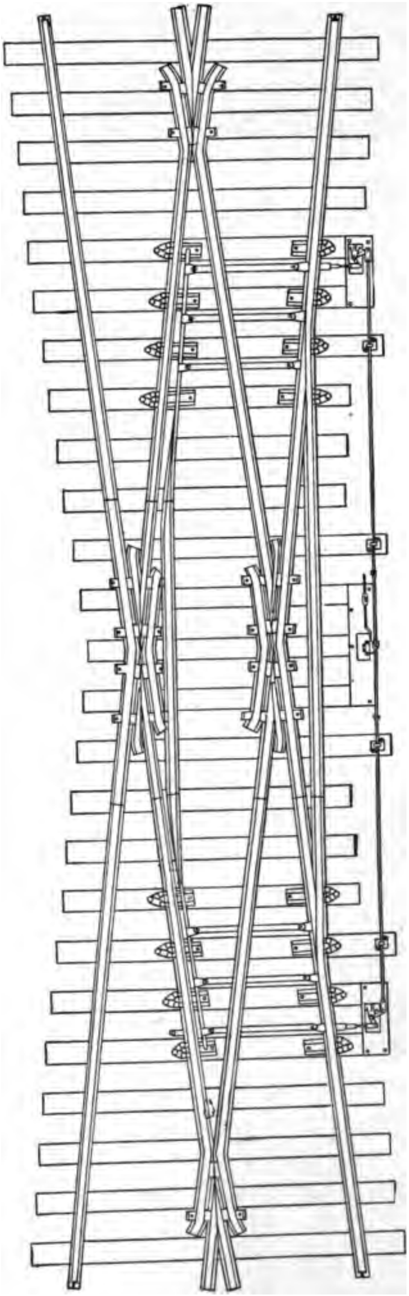


Fig. 135.

Example. *Locating a switch on a curved main track.* Given a main track having a 4° 30′ curve, to locate a turnout to the outside using a No. 9 frog; gauge, 4 ft. $8\frac{1}{2}$ in.; $f=6.00'$; $k=5\frac{3}{4}$ in.; DM$=16.5$ ft.; and $a=1°\ 44'\ 11''$. Then for a *straight* track r would $=$ 616.27 ($d=9°18'\ 27''$). For the curved track d should be nearly $(9°\ 18'-4°\ 30')=4°\ 48'$, or $r=1194.0$. L for the straight track would be 72.61, but since the lead is slightly increased (say about 0.1—see § 121) we may call the lead 72.7, although this difference would be absolutely imperceptible after the track was laid, so far as train running was concerned. After locating the switch and frog point as described above, the frog and the switch rails should be placed. The closure for the curved rail is given in Table III as 42.92 and curving the main track would make it slightly longer still, say 43.0. $R=1194.0+2.35=1196.35$. Applying equation 55, we have $x=43.0^2\div(8\times1196.35)=0.193$, the ordinate at the middle point. The ordinate at each quarter point is three-fourths of the ordinate at the center, or, in this case, 0.145.

131. Slip Switches. The complicated demands for switching in yards and terminals have been greatly assisted by the device



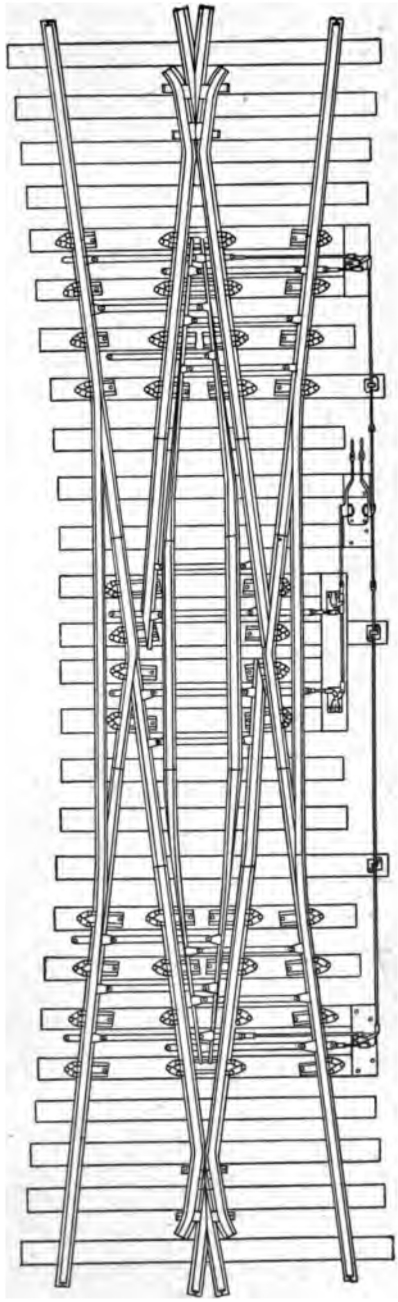


Fig. 136. Slip Switches. Fig. 137.

known as slip switches, illustrations of which are shown in Figs. 136 and 137. Fig. 136 shows a "single slip" in which the two middle frogs are fixed, although the system of movable frogs illus-

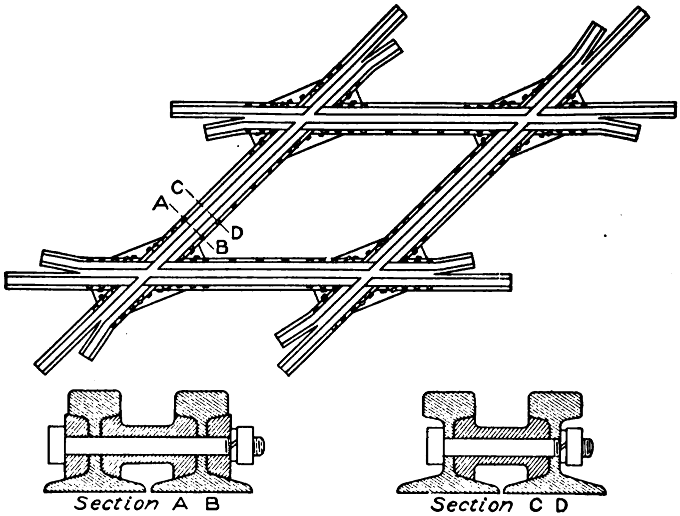


Fig. 138. Crossing.

trated in Fig. 137 is especially applicable. The double slip switch illustrated in Fig. 137 makes it possible for a train coming on either track to run directly on to either of the opposing lines. It should be noted that the mechanism is made interlocking so that the setting of a switch at one end will simultaneously set the switch at the other end as is required.

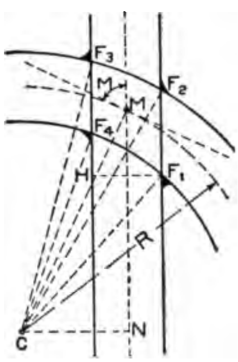


Fig. 139.

132. Crossings. When two railroads cross each other or even when it is desired to have one line cross another without having any switch connection, a crossing may be used. If the angle should be small (which is very undesirable) the method of movable frogs, shown by the crossing of the inner main rails of Fig. 137, may be used. But the lines should be required to cross each other as nearly at right angles as possible and then a bolted or riveted set of frogs, with fillers between the rails, such as is illustrated in Fig.

138, may be used. In general these crossings will need to be made to order according to the angle between the two lines. Since such crossings are sometimes operated at very high speeds the construction must be especially strong and rigid. When both tracks are straight the frog angles are identical, or more strictly, two of them are "complements" of the other two. When one or both tracks are curved, all four frogs will be different and the computation of their exact value becomes a somewhat complicated geometrical problem. The mechanical construction need not be essentially different from that shown in Fig. 138.

133. Crossing. *One straight and one curved track.* In Fig. 139, R is known and also the angle M, made by the center lines at their point of intersection.

$$M = NCM \text{ and } NC = R \cos M$$

then $(R - \frac{1}{2} g) \cos F_1 = NC + \frac{1}{2} g$

$$\therefore \cos F_1 = \frac{R \cos M + \frac{1}{2} g}{R - \frac{1}{2} g}$$

Similarly it may be proved that

$$\cos F_2 = \frac{R \cos M + \frac{1}{2} g}{R + \frac{1}{2} g}$$

$$\cos F_3 = \frac{R \cos M - \frac{1}{2} g}{R + \frac{1}{2} g} \qquad (100)$$

$$\cos F_4 = \frac{R \cos M - \frac{1}{2} g}{R - \frac{1}{2} g}$$

To find the relative positions on the tracks of the frogs, we may write

$$\left.\begin{aligned}
F_3F_4 &= \left(R + \frac{1}{2}g\right)\sin F_3 - \left(R - \frac{1}{2}g\right)\sin F_4 \\
HF_4 &= \left(R - \frac{1}{2}g\right)(\sin F_4 - \sin F_1) \\
F_1F_2 &= \left(R + \frac{1}{2}g\right)\sin F_2 - \left(R - \frac{1}{2}g\right)\sin F_1
\end{aligned}\right\} \quad (101)$$

It should be noted that F_3F_4 will not be exactly equal to F_1F_2 although the difference will be very small.

134. Crossing. *Both tracks curved.* The angle of the tangents (or radii) at their point of intersection is a known quantity (M) and also the two radii R_1 and R_2. But since we must deal directly with the radii of the inner and outer rails of both curves, it will be easier to immediately add (or subtract) $\frac{1}{2}g$ to R_1 or R_2 and thus obtain r_1, r_2, r_3, and r_4, as indicated in Figure 140. Referring to the triangle $F_1C_1C_2$, and calling $s_1 = \frac{1}{2}(c + r_1 + r_4)$, we may write:

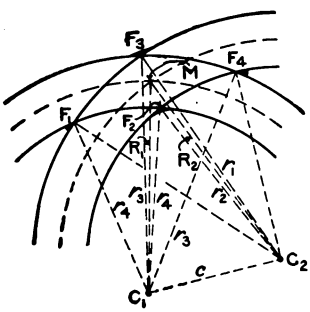


Fig. 140.

$$\left.\begin{aligned}
&\operatorname{vers} F_1 = \frac{2(s_1 - r_1)(s_1 - r_4)}{r_1 r_4} \\
&\text{Similarly in the triangle } F_2C_1C_2, \text{ let } s_2 = \frac{1}{2}(c + r_2 + r_4) \\
&\text{and in the triangle } F_3C_1C_2, \text{ let } s_3 = \frac{1}{2}(c + r_1 + r_3) \\
&\text{and in the triangle } F_4C_1C_2, \text{ let } s_4 = \frac{1}{2}(c + r_2 + r_3) \\
&\text{and then we may write} \\
&\operatorname{vers} F_2 = \frac{2(s_2 - r_2)(s_2 - r_4)}{r_2 r_4} \\
&\operatorname{vers} F_3 = \frac{2(s_3 - r_1)(s_3 - r_3)}{r_1 r_3} \\
&\operatorname{vers} F_4 = \frac{2(s_4 - r_2)(s_4 - r_3)}{r_2 r_3}
\end{aligned}\right\} \quad (102)$$

To determine the length of track between the frogs we may write

$$\sin C_1C_2F_4 = \sin F_4 \frac{r_3}{c}$$

$$\text{and } \sin C_1C_2F_2 = \sin F_2 \frac{r_4}{c}$$

$$\therefore F_2C_2F_4 = C_1C_2F_4 - C_1C_2F_2 \qquad \textbf{(103)}$$

Knowing the angle $F_2C_2F_4$ we readily determine that the chord $F_2F_4 = 2r_2 \sin\frac{1}{2}(F_2C_2F_4)$. In a precisely similar manner the chords F_1F_2, F_1F_3, and F_3F_4 may be computed. As a check, it should be found that all these chords are nearly although not quite equal. Likewise the mean of all the four frog angles should be within a few seconds of the value of M.

135. Examples. 1. Determine the dimensions and the frog angles for the crossing of a straight track with a track of 4° curvature (as in Fig. 135) when the angle M = 72° 18′.

2. A 2° curve crosses a 4° curve as in Fig. 140, the angle M being 52° 20′. Determine the frog angles and the chord lengths between the frogs.

YARDS AND TERMINALS.

136. Value of a Proper Design. When a freight train arrives at a terminal yard, which is generally in a city of considerable size, with one or more other railroads or branches, the train load will in general be made up of some cars which will need to be shifted to some other road or division or to be shunted on to a siding where they may be unloaded. If the character of the train is mixed, partly coal and partly general merchandise or grain, the coal cars must be sent to their own tracks and the merchandise to theirs. A "division" point of a road is frequently the terminus of one or more branches as well as the point where freight trains are perhaps made up anew, especially if the ruling grade on adjacent divisions is so different that the train load which can be hauled by one engine is very different on the several divisions.

A little study of these facts, together with others which will readily suggest themselves in this connection, will show the vast amount of work which is necessary in sorting out the cars in a yard.

Often the road engine is cut off from the train as soon as it has brought it to its proper place in the yard, and the distributing is done entirely by switching engines. But the work in large yards is so great that several engines will be required for the work. The cost of running a switching engine per day may be figured as approximately \$25. If the design of a yard can be so altered that one engine can be dispensed with, or that three engines may be made to do the work which formerly required four, we would have in 313 working days per year an annual saving of \$7,825, which capitalized at 5%, gives \$156,500 which is sufficient to reconstruct almost any yard.

As will be developed later, such a saving is by no means an impossibility. The requirements for space for water stations, ash-pits, coaling stations, turntables, sand and oil houses, engine houses, etc., and their proper arrangement so as to avoid useless running of the engines, is another feature which shows the value of a systematic design for a yard. When a yard is being constructed at a new place, it may be designed on the basis of subsequent work, no matter how little of it is immediately constructed, but very many yards were laid out when the now recognized principles were unknown. Subsequent additions have only made a bad matter worse until it is seen that an entire re-construction is necessary to make the yard what it should be.

137. Freight Yards. General Principles. A yard built on an ideal plan is in general an impossibility. Topographical considerations usually influence the problem to such an extent that the only method is to study the location so that certain fundamental principles may be applied.

1. A yard is a classifying machine for receiving, sorting and despatching cars to their several destinations as rapidly as possible. Its efficiency is measured by the rapidity with which it accomplishes this and the economy of motive power which is required.

2. At a yard which is the terminal of a division the freight trains are pulled in to a "receiving track" so as to get them out of the way and off of the main track. The road engine is then run off to the engine yard where it is cleared of ashes, loaded with water, coal, sand, etc., and otherwise prepared for its next trip. Perhaps the caboose is run off to a "caboose track" the location of

which is made convenient. Then, if the train is a "through" freight, another engine and caboose may be attached and it may proceed unbroken unless a change in ruling grade requires a different train load.

3. There are certain tracks in a yard which may be considered the skeleton of the yard. On these tracks no trains should be allowed to stand except temporarily. Such tracks, shown in Fig. 141, in which each pair of rails is indicated by a single line, are called "ladder tracks," and from these the storage tracks are run in parallel lines. Other through tracks are indicated on the plan.

4. The storage tracks should usually be made double-ended or with a ladder track at each end. This usually facilitates the switching by permitting one or more cars to be drawn from either end without disturbing the cars at the other end of that track.

5. In recent years many yards have been made by creating an artificial hump at such a place that the grade from the ladder tracks on to the storage tracks is about 0.5 per cent. This creates a gravity force of 10 pounds per ton which is sufficient to cause a car to roll by gravity from the ladder track on to any storage track to which it may be directed. In this way a train of cars on the ladder track may be distrib-

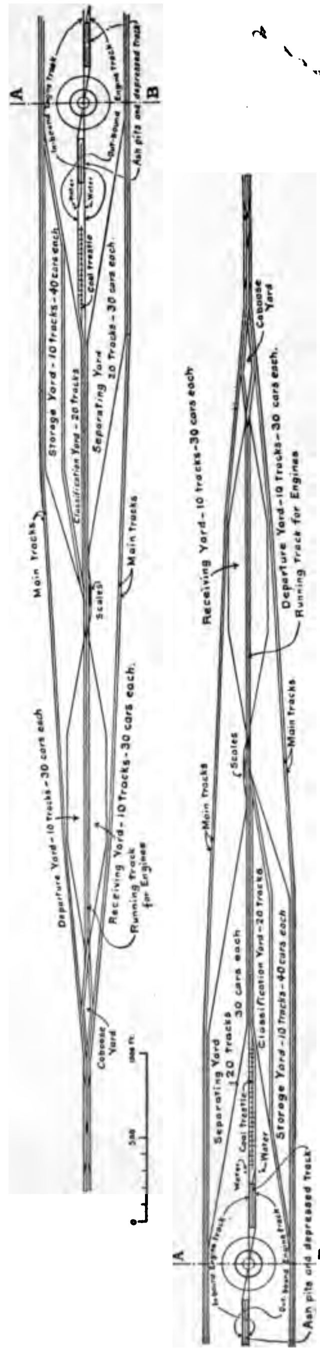


Fig. 141. Plan of Typical Freight Yard.

uted to the various storage tracks with great rapidity. Incidentally there is no danger of a car running out from the storage track on to the ladder track. Symmetry and economy of space will usually require that the frogs and the switch dimensions of the switches running off from the ladder tracks shall be uniform. No. 7 frogs are very commonly used; frogs with a larger frog number make an easier riding track, but they require more space, and limit the space which may be used for storage. No. 6 and even No. 5 frogs are sometimes used on account of the economy of space which is thereby obtained, but it makes harder rolling and greater danger of derailment.

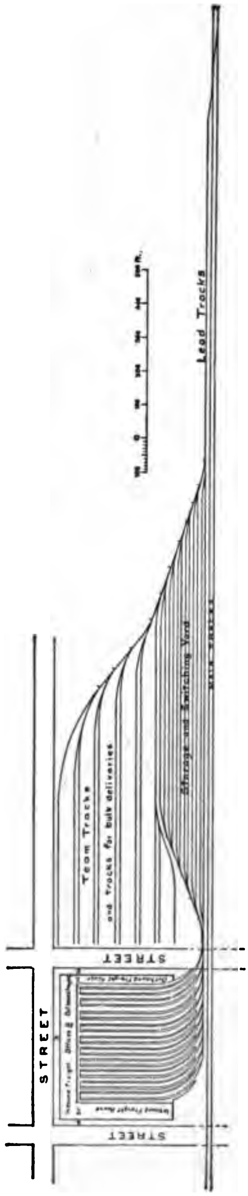


Fig. 142. Local Freight Yard.

138. Connection of Freight Yard with Main Tracks. As a general principle the main tracks should be as clear as possible from the yard tracks so that passenger trains may run through freely at any time without even the danger of a collision with any freight cars or of interfering with the work of the freight yard. This practically means that there should be no crossing of the main tracks by any tracks used in yard operations and that the connection should be only where it is desired to run from the main tracks on to the receiving tracks and that here the switches should be thoroughly protected by signals. The ideal construction is to have (on double track roads) all opposing tracks cross over or under each other so that two trains will never approach the same point of track except when they are moving in the same direction and then the danger of a collision will be largely averted. The receiving tracks (or similar tracks) should be utilized as "departing tracks"

on which outgoing freight trains may wait for their signal to start without interfering with any passenger traffic on the main line tracks or any shifting work in the yard.

139. Minor Freight Yards. The name applies to the local collecting or distributing yards which are located in parts of a great city where the freight business is especially large. The cars are brought to these yards by means of long switches or by means of floats when the yard is located on a water front. The special feature of these yards is the fact that since they are always located on very valuable land, great ingenuity is required to utilize the limited space to the greatest advantage. This usually requires excessively sharp curvature, which may be limited by the fact that car couplers will not permit the car bodies to make a large angle with each other. The shortest permissible radius is 175 feet and even this is undesirable. Radii as short as 50 feet have been used in some yards, but in that case an extension coupling bar is placed between the cars. Yards for receiving or distributing freight should be provided with team tracks which are made stub-ended and which are preferably placed in pairs with a sufficient space for roadway between each pair.

Figures 141 and 142 are ideal plans which were submitted to the American Railway Engineering and Maintenance of Way Association at its meeting in March, 1902. As "ideal" plans, it is not supposed that they can be literally adopted, but a study of them will show their general conformity with the principles stated above, and also will be suggestive of plans adapted to the local conditions.

140. Freight Yard Accessories. *Track scales.* These are for weighing freight cars on the track. When, as is frequently the case, the scales are located on a much used track, an auxiliary pair of rails is laid about six inches from the scale rails and connected with them by a split rail switch at a suitable distance from each end of the scales. One auxiliary rail is supported on the side of the scale pit and the other on several posts which run through the scale table floor. It has been found practicable to weigh a whole train load even in motion by running it very slowly over the scale tracks and noting the scale reading for each car when it becomes central over the pit.

Cranes. The frequent transportation of individual loads weighing many tons requires the use of some sort of unloader, which may vary from the temporary "gin pole" to a traveling crane which strides one or more tracks and a roadway, and which may travel on rails parallel with the switch tracks and also has a "traveler" which runs perpendicular to the tracks. The double horizontal motion (as well as the vertical motion) permits the loading or unloading between any car and wagon placed within its range. While their use is somewhat limited, there are occasions when they are almost indispensable.

141. Engine Yards. The ideal position for the engine house with its accessories is in the center of the yard, as is shown in Fig.

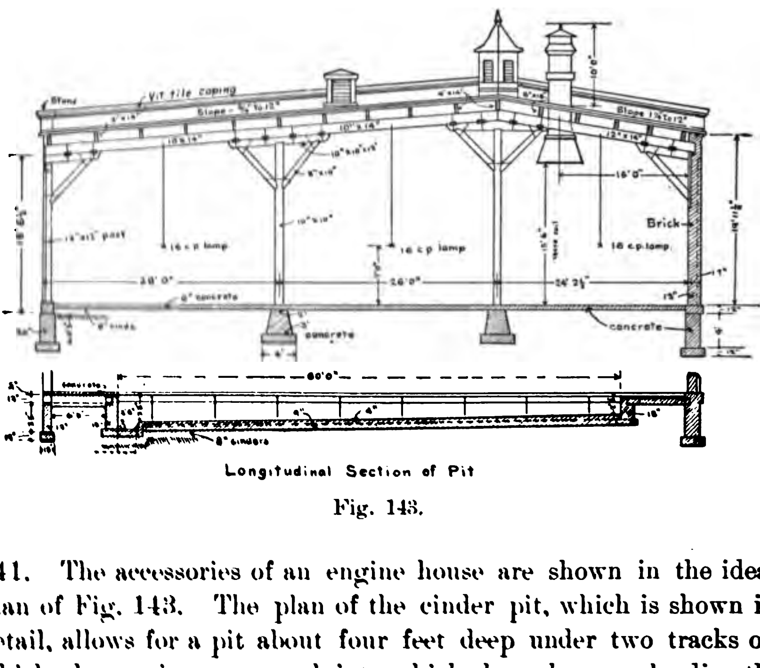


Fig. 143.

141. The accessories of an engine house are shown in the ideal plan of Fig. 143. The plan of the cinder pit, which is shown in detail, allows for a pit about four feet deep under two tracks on which the engines run, and into which the ashes can be directly dumped. These tracks are each side of a depressed track which is sunk to such a depth that the sides of a gondola car will be below the bottom of the ashpits under the engine tracks. The dumped ashes can therefore be very easily shoveled into the car in the depressed track.

Passenger terminals for large cities are structures which demand the services of an architect rather than an engineer. The engineering features are largely those of elevating or depressing the approaching tracks so as to avoid the grade crossing of city streets, and all such problems must be solved individually. Those who wish to study the subject further may find it treated very fully in "Buildings and Structures of American Railroads," by Walter G. Berg.

SIGNALING.

The following description of signaling is not to be considered as a complete course on the subject as that would require more space than may here be devoted to it. The discussion has been condensed to such fundamental facts as every railroad engineer should know. The development of the science has been so rapid during late years that one must follow current engineering literature to keep abreast with the progress of the work. A student desiring a more throrough course in the groundwork of the subject is referred to "The Block System," by B. B. Adams (234 pages), as well as to similar but earlier works by W. H. Elliot and W. L. Derr.

142. Systems. When railroading was still in its infancy but traffic had so increased that rear-end collisions on double track became an imminent danger, two general plans were suggested and tried to guard against such accidents—(*a*) the time interval system and (*b*) the space interval system. Although some traces of the first system are still to be found in train order systems and in operating rules and time tables, it has been found inadequate for the operation of heavy traffic. When trains are run close together, even a short delay becomes a source of danger, which is only partially obviated by vigilant work by the rear flagman, and even this safeguard is only obtained at the expense of further delay in waiting for the flagman to return to the train after the cause of the delay is removed and the train is able to proceed. The space interval system has therefore become the basis of all modern systems.

Considered from another standpoint, the methods of handling trains may be divided into two general classes—(*a*) the telegraphic order system, in which men at different parts of the line receive

orders by telegraph regarding the movements of trains which will soon pass them and who communicate these orders to the trainmen either verbally or by signal, and (*b*) those systems under which the signals at any point are controlled by mechanism at adjacent points. The fundamental difference between the two systems is that in the first case a blunder by any *one* of several men may cause an accident; in the second case, blunders are, to a considerable extent, mechanically impossible, and when made are generally immediately apparent to one or more others, and may be corrected in time to prevent an accident.

Fig. 144.

The first system includes the method by which a large proportion of the trains of the country are operated —the "train order" system, which will not be here elaborated since "signals" are not a necessary feature of it. Under this method the train crew receive their orders, issued by the train despatcher of the division, which are written out by the telegraph operator at the local office where received. The train is then run in accordance with such orders until it reaches the next train order office. The first system also includes the simple manual system, described in the next section. The various systems of controlling the signaling, culminating in the absolutely automatic system, will be successively described.

143. *Simple Manual System.* In this, as in all other block systems, the road is divided into sections or "blocks" whose lengths are varied somewhat to suit the method adopted and the natural conditions, and also are made roughly proportional to the traffic. For example, on the main line of the Pennsylvania Railroad between Philadelphia and Harrisburg the sections have an average length of a little over two miles, a few are four miles long, and some (especially where the suburban traffic is heaviest) are less than one mile long. On the other hand, on a road with less traffic (although sufficient to require the block system), the blocks might have a much greater length. "Absolute" blocking forbids the entrance of a train into

a block until the preceding train has passed out of it. This practically means that the trains must average considerably over one block apart, since train B (see Fig. 144) cannot enter the block (2—1) until train A has passed out of that block, and the fact is telegraphed back so that the signals at (2) may be set for train B to enter the block. Train C and the succeeding trains must virtually maintain the same interval even though they temporarily move up closer. At a freight train speed of 15 miles per hour, trains could be run through blocks five miles long at intervals of twenty minutes plus the time required for signaling between stations and for the trains to pass by the signal station. Under the simple manual system the rules of operation, although varied in detail, are essentially as follows for double-track work:

When train A has passed (1) the operator there telegraphs the fact back to (2), and then the operator at (2) knows that the block from (2) to (1) is clear and that he can admit train B to the block. If train B does not arrive at (2) for some time afterward, (2) should obtain definite word from (1) immediately before B is due that the block is clear, since it might have become obstructed by switching operations or otherwise. As soon as train B has passed (2) the fact is telegraphed back to (3), which informs (3) that the block (3—2) is clear. The method of communication is usually by the ordinary Morse alphabet, but since the facts to be communicated are very few and simple, a system of taps on electric bells, which can be more easily and quickly learned than the Morse alphabet, are sometimes used. During recent years even the telephone has been used for this purpose. Some of the mechanical details of this method will be given later. Each road employing such a system has a more or less elaborate set of rules governing the operation of the signals, whose object is to make the work as mechanical as possible, to guard against giving wrong signals and to locate the blame when an error is made.

It should be noted, however, that there is nothing to prevent a signalman from giving a "clear" signal, when he should show a "stop" signal, even when he has been instructed otherwise and has perhaps reported by telegraph that he has obeyed orders. In short he is not "controlled," and in case of an accident there is a

question of veracity between him and the engineman. The system has the merit of cheapness, since the signals may be of the cheapest form and the intercommunication may be done by the cheapest form of telegraphic circuit.

Permissive Blocking. There is a variation of the "absolute" system which is also applicable to some of the following systems and which facilitates traffic although at some sacrifice of safety. Under this system, a train is allowed to proceed into a block even though there is a train still there. But the train must be under "perfect control" (some rules limiting the speed to six miles per hour) so that it may be stopped very quickly if necessary. By this means, the delay of a succeeding train, and perhaps of several following trains, is very greatly reduced. Of course such a practice requires extreme caution to avoid accidents, and there are very minute rules to be followed when such running is permitted at all.

When heavy passenger trains are run at a speed approaching 60 miles per hour, it becomes impracticable to make a "service" stop much within 1,500 feet. Although a stop *may* be made in a much shorter distance, it induces very severe strains in the rolling stock and hence should be avoided. But since it is frequently impossible, on account of curves or other obstructions, to see signals more than a few hundred feet away, an engineman dare not approach a "home" signal at very high speed for fear a stalled train may be immediately beyond it. Therefore a "*distant signal,*" which forewarns the engineman of the indication of the "home" signal, is placed 800 to 2,500 feet from the home signal. The required distance, which for mechanical reasons is made as short as possible, except as noted below, depends on the grade and on how far from the signal it may be clearly seen.

When the distant signal is set for "clear," the engineman knows that he may proceed at least as far as the *second* home signal ahead; when it is set for "caution," he knows that he may proceed at least as far as the next home signal, but he must expect to be stopped there and he must have his train under such control that he can stop there if required. Sometimes the signal becomes cleared by the time he reaches the home signal and there is no actual delay beyond a slight reduction in speed, but the indication of the distant signal enables him in any case to approach the home

signal confidently, knowing beforehand that it will be "clear" if the distant signal was "clear." In any system where the signaling is "controlled," such a distant signal is locked so that it cannot indicate clear when the home signal indicates stop. Under the "automatic" systems the distant signal is usually placed on the same post as the home signal for the preceding block. In this case, when the distant signal indicates clear, the engineman knows that his road is clear for two full blocks, but he may have to slacken speed when he reaches the next block station.

144. Controlled Manual System. In the previous system the only connection between the signal stations is the telegraphic communication of information. The "controlled manual" system includes the following essential elements. The signals at each station are locked by electromagnets which are controlled electrically from the signal station ahead. When a train approaches (*1*), (*1*) must notify (*2*) of it. If the last previous train has passed (*2*) and there is no other impediment, (*2*) will unlock (*1*)'s lever electrically, so that it is possible for (*1*) to set a clear signal. After the train has passed (*1*), the signal at (*1*) is set for the "stop" position. It will then be impossible for him to set it clear again until permitted to by (*2*). Knowing that the train is coming, (*2*) inquires of (*3*) if the block (*2—3*) is clear and if so (*3*) will unlock (*2*)'s lever so that it can be set for clear. The above is the simplest and earliest form of such a system.

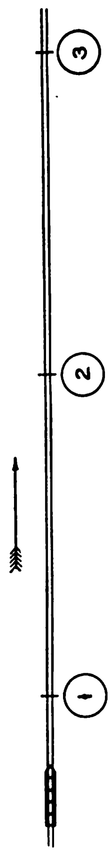


Fig. 145.

The chief advance over the simple manual system lies in the mutual control of the signal offices on each other. A signalman cannot set a signal clear except by the action of the next signalman ahead who thereby certifies that the block ahead is clear. The chances of error are thereby decreased. The electrical control is maintained over a "wire circuit," but the system is made much more under control by adopting features which are essentially those of the automatic system. The two rails of the track are carefully insulated from each other, and, near each signal station, the abutting rails are insulated at

some joint by joining them with insulated joints such as are described in section 107.

At B, Fig. 146, a track battery sends a current through the rails which energizes the track relay at A, which operates the signal mechanism at A. The presence of even a single pair of wheels on the track between A and B, or even on the siding up to the "fouling point," will cause the current to be short-circuited and it will fail to energize the relay at A. By this means it is readily arranged that when the train passes A, A's signal will automatically fall to "stop" and will become locked there so that it cannot become unlocked until the train passes the insulated joints at B. When the train passes B, the current through the relay will then become strong enough to release the lock and then A can set his signal to "clear" if permitted to by B.

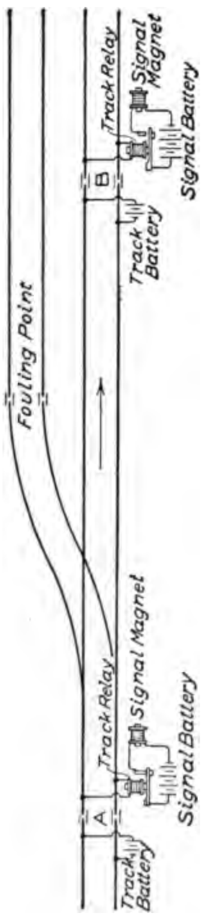


Fig. 146.

The method involves both a wire circuit and a track circuit. But when the sections are very long, it becomes very difficult to control the track circuit so as to avoid leakage and yet give the current sufficient strength to do its required work. And so the method is still further complicated by eliminating long stretches of the track circuit, but retaining it in the track near each signal station so that the signals will be automatically operated and controlled as before.

It should be noted that if a car was standing on the siding and was moved toward the switch point by wind, or through malicious mischief or otherwise, as soon as it passed the fouling point the signal at A would automatically go to "stop" and the signal would stay locked until the track was cleared. A broken rail would have the same effect of locking the signal and would start an investigation to determine the trouble.

145. Automatic Systems. Some of the principal essentials of the automatic systems have already been described above. Some

of the differences are as follows. The mechanical work to be performed by the electric current in the controlled manual system is limited to unlocking certain mechanisms or unlocking the signals so that by gravity they will assume the "stop" position. The heavy work of moving the signals, which are usually of the "semaphore" type (described later) is performed by the signalmen. But automatic signals must be worked by a mechanism which always has sufficient power to move the signals. This practically means that the signals must have such a form and be so worked that but little force will be required to move them.

The earliest forms were targets mounted on a vertical axis which was swung around by clockwork. When set for "stop" a red target would show; when set for "clear" the red target would turn edgewise and a white target of different form which was previously edgewise (or perhaps no target at all) would then show. A lantern, with red lenses on two opposite faces and white (or green) lenses on the other two faces would be set on top of the axis. A weight moving up and down in a hollow iron post, would be periodically wound up to provide the power. Each time the signal is changed from "stop" to "clear" or from "clear" to "stop" the axis turns one-quarter turn. One objection to the method lies in the fact that since putting even a handcar or a track gauge on the rails will turn the signal to danger and taking it off will restore it to clear, the mechanism will be made to work so often that it will require rewinding with annoying frequency and then perhaps become run down and fail to work.

To guard against one source of danger, the mechanism is made to open the circuit and thus put the signal to "stop" just before it becomes run down, so as to avoid the possibility of the signal indicating clear when it should indicate danger. The clockwork system is still in successful use on some of the systems where it has been installed many years, but the more recent designs use an enclosed disk signal (described later). An important detail is the placing of the signal 200 feet in advance of the entrance of a block section. This enables the engineer to *see* the signals turn to danger as a result of his entering the block and he thus knows that there is a signal protecting him until he reaches the next signal.

If the signal fails to work, it shows that there is something wrong with the mechanism and he will take precautions accordingly.

Another advantage of the track circuit system lies in the fact that if a switch be opened anywhere in a block, the switch being provided with a circuit breaker, the circuit will be broken and the signal will automatically fall to danger. In short, almost any defect or impediment to a clear track will be indicated by the signal. And herein lies one troublesome feature: the circuit is so sensitive that any accidental short-circuiting (even though not due to any defect or obstruction of the track) will delay traffic. The opposite (and far more serious) error in operation—indicating "clear" when it should indicate "stop"—will only be caused by a defect in the mechanism, and the record in that respect is very good, the proportion of such errors to number of signal movements being exceedingly small.

146. Mechanical Details. The train order system does not necessitate signals of any kind, but on many roads which make no claim to a block signal system a signal of some sort will be displayed from the local train-order office. The signal may be a mere flag on a stick; an improvement is to hang it from a horizontal support, the lower edge being weighted, the whole being provided with a cord which is run back to the office, which permits the ready display or removal of the flag. Some western railroads have improved these by using some "home-made" signals operated similarly, but using a target made of thin wood or of sheet metal. From this it is but a short step to the standard "semaphore," illustrated in Fig. 147 and elsewhere.

The semaphore consists essentially of a board about five feet long, eight inches wide at the outer end and six inches wide at the hinge end. The hinge is a somewhat elaborate casting with one or more "spectacles" as holders of colored glass lenses. Since the weight of the casting on the spectacle side is usually not sufficient to overbalance the weight of the semaphore board, a counterweight is so attached that if the rods or wires to the signal cabin should break, the signal will automatically assume the horizontal position, which is universally considered as the "stop" or "danger" signal. When the axis of the board passes through the hinge bolt, as is

shown in Fig. 147, the "clear" position is given by inclining the board at an angle of 45°, as shown in position B.

Another form is to have the board eccentric to the hinge, so that it may be dropped to a vertical position and still show outside of the post. As a general principle of construction, the board should be clearly visible even in foggy weather, and therefore the board should not come down directly in front of the post, for in foggy weather it would not be clearly visible and an engineman might pass the signal thinking it was in front of the post, when it might have been broken off and should have indicated danger. Fig. 147 shows a wooden post; the latest high-grade practice now uses iron posts with suitable castings at top and bottom. One advantage of such posts is the placing of the rods inside of the post where they are less subject to interference from snow and sleet and from malicious mischief.

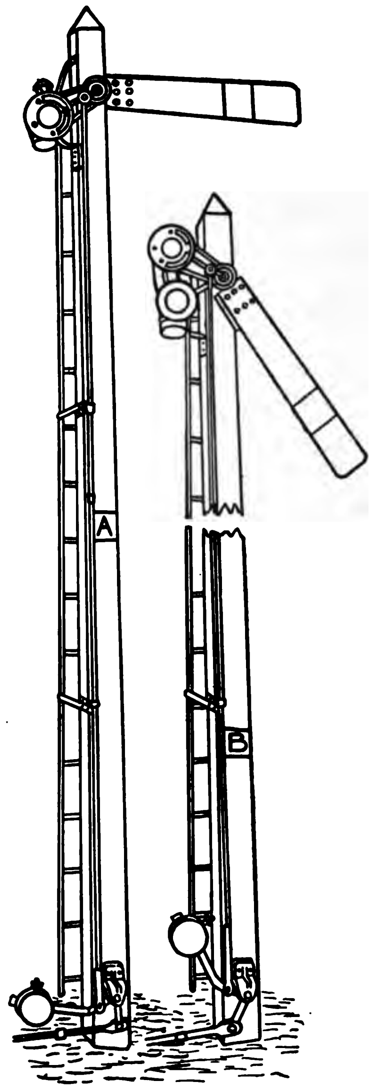


Fig. 147. Semaphore.

The boards are always set so that they point to the right from the track which they govern, or in other words a signal which points to the left of its supporting pole, as seen by an approaching train, governs trains moving in the opposite direction. Sometimes the boards are painted red on the governing side and white on the other side, but whatever the variation in practice the indication is inde-

pendent of the color, and on some roads the color is "neutral," so as to emphasize the fact that the engineman must be governed by the *form* and *position* of the board rather than by the color.

The only essential variation of form of the blade lies in making the ends of all home signals square and of all distant signals notched or of a "fishtail" form. One other form used for the dis-

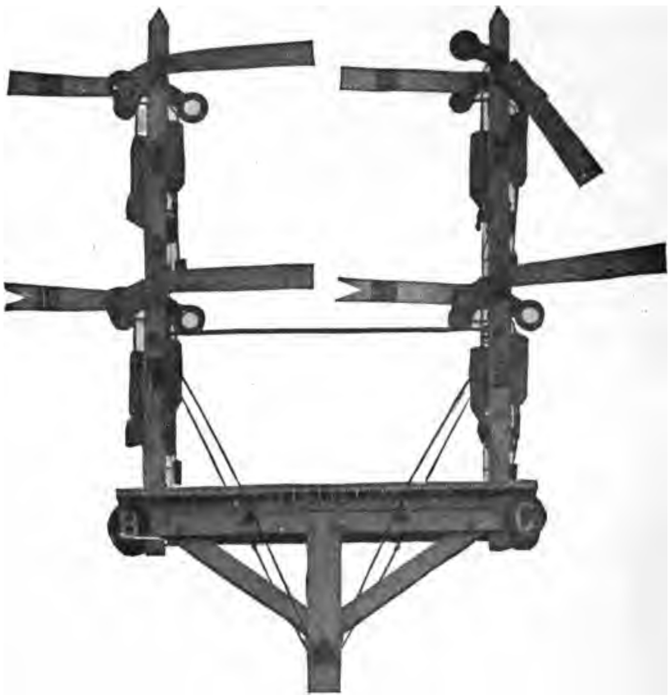


Fig. 148.

tant signal is to make it pointed. When there are but two tracks the semaphores are usually placed on separate posts on each side of the roadbed. Even when there are four tracks, the signals for the two tracks on each side may be placed on one main pole which has a cross-arm and two uprights, each carrying one or more semaphores, as shown in Fig. 148. But when there are more than four tracks (as in yards), and frequently on four-track roads, the signals are carried on a "bridge" such as is illustrated in Fig. 149. In such a case the signals for each track are placed directly over the track.

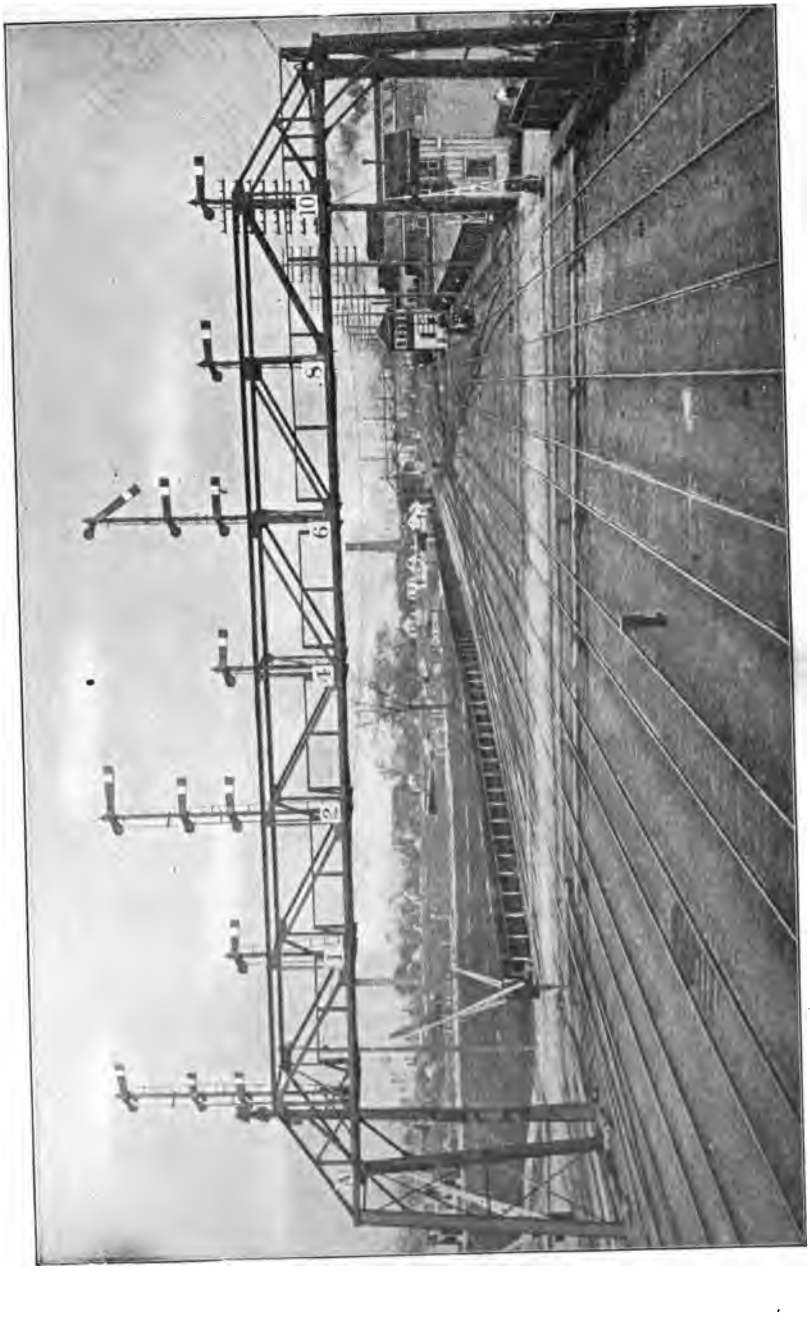


Fig. 149. Semaphore Bridge.

When more than one square-ended signal is over a track, the upper one refers to the through track and the lower ones to the switches which will be immediately encountered. Note in Fig. 149 that the signal bridge in the background has boards on the *left* side of the posts and that they are evidently *white*. This shows that the bridge governs movements *toward* the observer, while the signals on the bridge in the foreground evidently govern train movements in the direction the observer is looking. The mechanism of all such signals is necessarily somewhat exposed, and is liable to be actually blocked when covered with snow and sleet. A considerable amount of power must therefore be available to operate such signals.

Another form in extensive use is the enclosed signal.

Enclosed signals. There are two great arguments for and against the use of such signals. On the one hand, the mechanism is entirely enclosed and protected from the weather and is therefore uninfluenced by wind, snow or sleet. Also the mechanism can be made so very light and delicate that it requires only a small percentage of the power required to operate semaphores, and therefore they can be operated by an electric current of very low voltage. On the other hand, the signal is not one of *form* and *position* but of *color* only. It is argued that it cannot be as clearly seen in stormy weather and on that account is less safe. While it is unquestionably true that the signal indication is less visible in bad weather than a semaphore, yet the net advantages of the system are such that the system is very largely used.

The external appearance of the top of the signal (the post being omitted in the illustration) is as shown in Fig. 150. "Clear" is indicated by the disk opening showing white. To indicate danger a very light screen, made by stretching red silk over a light hoop, is swung over the opening. At night the lantern on the rear side shines through the opening, showing white or red according to the position of the screen. The detail of the mechanism, shown in Fig. 151, explains its operation. When the magnet is energized the disk is drawn up out of view and the signal shows white. If the current fails for any reason, the disk falls by gravity and comes into view. The power required is so small that the magnet not only controls the signal but also develops the power to move it.

147. Wires and Pipes. Wires are used for the transmission of electric current and pipes are used to transmit pneumatic pressure—as discussed later. But the above heading refers to wires

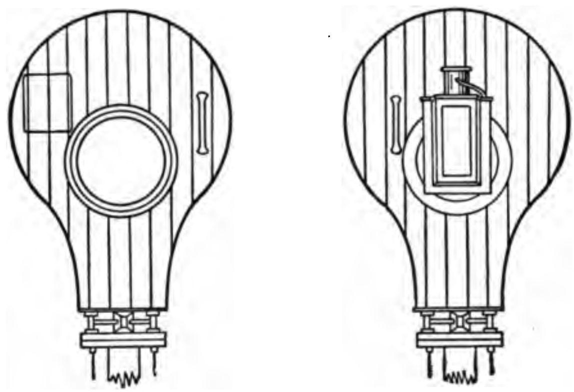


Fig. 150. Enclosed Signal.

and pipes as used to mechanically transmit motion from the signal cabin to the signal. When the parts may be made to work by tension, No. 9 wires may be used. When it is required to turn a right angle a grooved wheel is used and a short length of chain

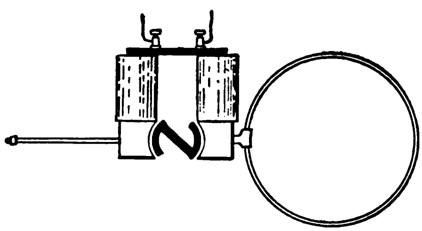
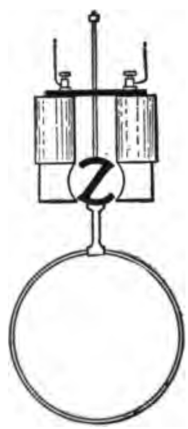


Fig. 151. Hall Automatic Signal Magnet.



is substituted for the wire. Slight deflection for pipes is accomplished by means of a series of bent rods running through guides, as shown in Fig. 152. If the deflection is greater, each rod must have a "bell crank." It is possible to work a signal with one wire, depending on gravity for the reverse motion, but good practice requires a wire for each motion. Signals are

sometimes operated mechanically at a distance of 2,000 feet from the cabin. For such, wires are practically a necessity, but when the signals are nearer, pipes which may exert a push as well as a pull are used.

Compensators. The coefficient of expansion of iron is so high that the change of length in a wire or pipe several hundred

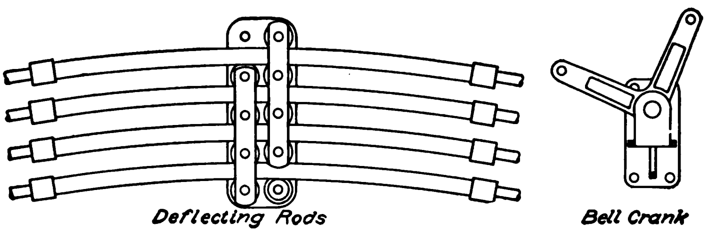


Fig. 152.

feet long is so great that the signaling mechanism is thrown out of adjustment unless there is some automatic device to counteract it. The change of length of 1,500 feet of wire due to a fall of temperature from 100° F. to 20° is $1500 \times 80 \times .0000065 = 0.78$ foot $= 9.36$ inches. A much less change than this would require adjustment. The geometrical principle of the automatic compensators is shown in the upper part of Fig. 153 and the practical construction is shown below it. By reference to the figure it may be seen that if the pipe ab contracts so that b moves to b', the point c would be moved to c', where $bb' = cc'$. But if $cd = ab$, dc would also contract to dc'. Therefore if the compensator is placed midway between the cabin and the signal, the cabin end of the pipe being fixed, a point at the signal end would retain its position regardless of any temperature change.

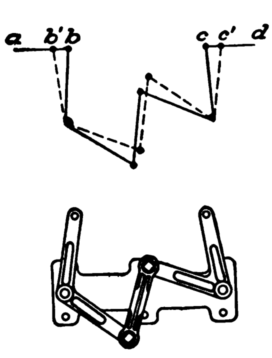


Fig. 153.

Practically these arcs should not be required tc work through too great an angle. It has been found that 500 feet is a desirable limit. Therefore if a signal was 1,000 feet away from the cabin, two compensators should be used, each placed 250 feet from the ends. Then the position of the ends and the middle point would

be unchanged by temperature. It should be noted that the insertion of such a mechanism changes the direction of the motion of the pipe; *i.e.*, if *ab* moves to the right *cd* will move to the left, and *vice versa*. Therefore one section or the other must be in compression, and such a compensator is applicable only to pipes. No compensator which is equally satisfactory has ever been designed for use with wires. They all require a spring or weight which takes up the slack, but if the wire gets caught somewhere this spring or weight may be pulled because its resistance is less, and then the signal does not operate. Several designs are in use and they work satisfactorily as long as the mechanism is in order.

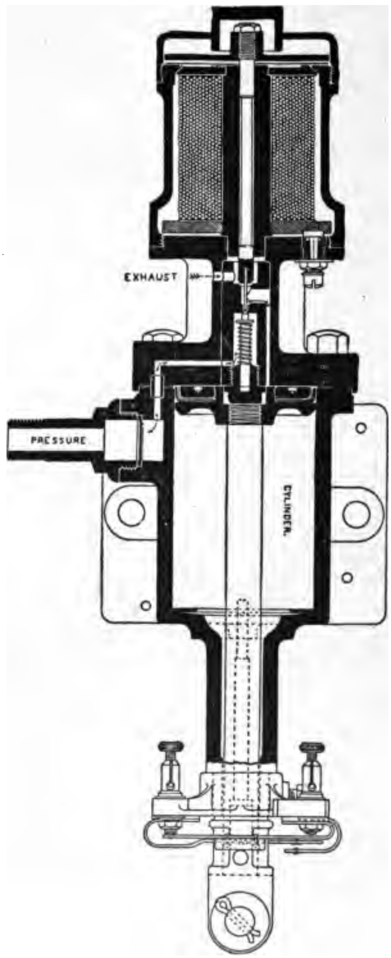


Fig. 154. Electro-Pneumatic Signal Mechanism.

148. Electro-Pneumatic Signals. The mechanical movement of signals by wires and rods is practically limited to about 2,000 feet and even at this distance it is troublesome. Electric power from batteries may be used when the power required is very small. An electro-pneumatic system uses compressed air whose power can be sent anywhere through pipes and which may be made to move not only signals but switches. The valves controlling the pistons are operated electrically by a current of low intensity, which may be provided by batteries but which in a plant of much magnitude is more economically obtained from storage batteries which are charged from a dynamo. The operation

of the valve is shown in Fig. 154. In the position shown the magnet is *not* energized. When it is, the armature (at the top) is drawn down, which opens the conical valve just above the spring, and the air passes from the pressure pipe through the valve and down the passage alongside of the valve chamber until it bears on the top of the piston, which is shown in its extreme upward position. When the piston is forced down, it will raise the counterweight (see Fig. 155) and put the signal at "clear." When the magnet is de-energized for *any* reason, the spring forces the valve up, the air in the cylinder escapes through the exhaust and the counterweight not only raises the piston to the top but draws the signal to indicate danger. A failure of either the current or the pressure will thus put the signal at danger.

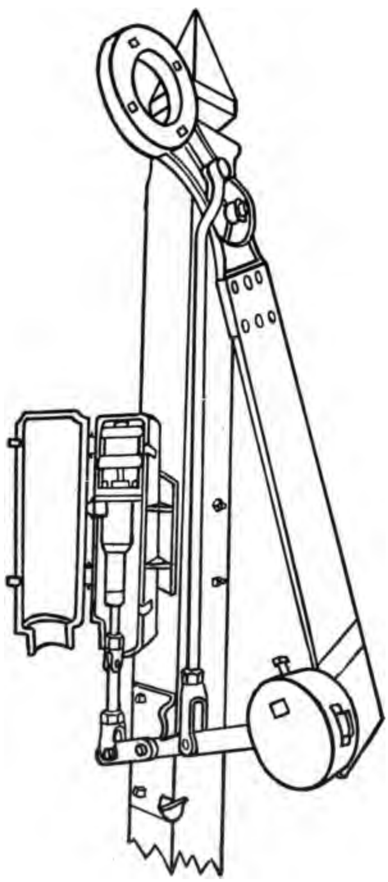


Fig. 155. Electro-Pneumatic Signal.

149. Electric Semaphores. Still another modification of automatic signals is the electric semaphore, which is a semaphore of the usual type, operated by an electric motor of about $\frac{1}{6}$ horsepower, the motor obtaining its current from a set of 10 to 16 Edison-Lalande battery cells which are placed in a box at the foot of the signal post. The motor winds up a light wire cable which raises the counterweight and thereby sets the signal at "clear." The motor is started and stopped by the action of a relay connected to the track circuit. The track circuit has the fundamental principles previously described, but has been made somewhat complicated so as to provide for the operation of distant

as well as home signals and also the protection of and from all switches in the section. For the details of the track circuits the student is referred to the more complete works on this subject previously mentioned.

INTERLOCKING.

150. Principles. The interlocking of the switches and signals of a large terminal yard is such a complicated piece of mechanism that any adequate explanation and description would require too much space here. Nothing will be attempted but a demonstration of the fundamental principle. The reason for the necessity of interlocking is simple. A mere inspection of the design of a complicated yard will show that it is readily possible to arrange a large number of combinations of different switch movements for the operation of an equal number of trains simultaneously. But the operation of such switches is controlled from a signal cabin, and unless there are limitations on the combinations a signalman would be liable to set switches and signals so that two or more trains might collide. The fundamental principle of the interlocking device is comprised in the following statements:

(*a*) all switch signals are normally at danger;

(*b*) no switch lever may be set for any route until the switches for any other route which might cause a collision have been locked;

(*c*) the signal cannot be set to run through any switch until the switch itself is set.

Although an engineman may cause a collision by running past a danger signal, the worst that a careless signalman can do is to delay traffic. He cannot set signals and switches so as to cause a collision or even a "side swipe." The design of the interlocking machine must therefore be based on a study of the safe combinations, and then the interlocking machine must have its "cross locks" and "locking dogs" so arranged that no interference is possible. The case illustrated in Fig. 156 has purposely been made as simple as possible. The upper part shows merely the locking dogs (shaded full black) which are fastened on to the "locking bars" (which run crosswise) and the "cross locks" (shaded with cross hatching), which move at right angles to the locking bars. In the lower part of the figure are shown the signals

and tracks for a crossover from a main track. No. 1 is the distant signal, No. 2 is the home signal governing the main track with respect to the crossover, No. 3 are the switch levers which work simultaneously, No. 4 is the signal governing movement from the siding to the main track, and No. 5 is the signal governing movement from the main track to the siding. No lever for a signal or a switch can be moved without simultaneously moving the locking bar (having the corresponding number) from right to left as shown in the figure.

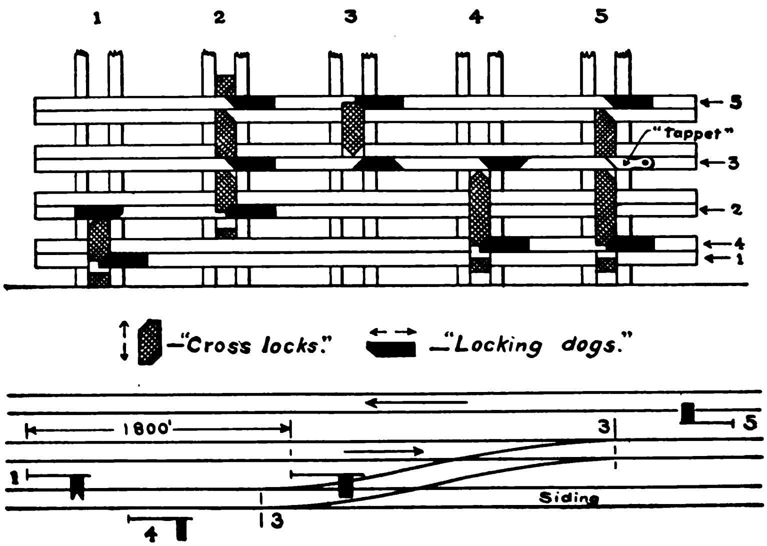


Fig. 156. Interlocking.

The wedge-shaped ends of the locking dogs will move (if possible) the cross locks with which they may come in contact. If any cross lock is immovable because it is already in contact with some other locking dog, then it will be impossible to move that lever until the lever (or levers) controlling all interfering locking dogs have been so moved as to remove the obstruction. The position of the locking dogs in Fig. 156 is that for all signals normal or at "danger." Suppose it were attempted to "clear" signal No. 1. To do so, locking bar No. 1 must move the cross lock No. 1. But this is impossible since one of the dogs on locking bar No. 2 interferes. Lever No. 1 cannot therefore be moved until

lever No. 2 has been cleared, which operation will move that dog far enough to the left so that the cross lock can move up. And this is in accordance with the principle previously stated that a distant signal should not be cleared until its home signal is cleared.

As another illustration, when the signal No. 2 has been cleared, the locking bar No. 2, by means of its attached dogs, moves the cross lock No. 2 upward. This cross lock is then set against locking dogs on each of locking bars No. 3 and No. 5 and prevents them from being cleared. Of course the signals for the crossover should not be cleared while the signal is set for a clear main track.

Exercise. The student should draw a modification of the upper part of Fig. 156, as it would be placed to indicate that the switch was set for a crossing from the siding to the main track. It should be noted that signal No. 4 is set "clear" when it is designed to move along the siding without using the switch, and No. 5 is set clear when the switch is set so that a train could run backward past the switch without using it. Both No. 4 and No. 5 are set at "danger" when it is designed to run from one track to the other.

The cross locks No. 1 to No. 4 inclusive are each in one piece with notches cut for the dogs. Cross lock No. 5 has the upper part separate. When the lower part is moved it does not move the upper part unless the "tappet" on locking bar No. 3 has previously been moved between the parts. The tappet is unnecessary with the simple combination of levers shown, but might be necessary with a somewhat more complicated system.

Of course the above description makes no mention of a multitude of details necessary for a manual machine, to say nothing of the complication required for an electro-pneumatic interlocking machine. But whatever the complication or how many may be the number of levers, the interlocking principle is as above.

TRACK MAINTENANCE.

151. Tools. Tools should be of good quality and well designed for their use. Economy in this respect, to save initial cost, is apt to increase the labor item and since the labor costs over 60 per cent of the total cost of track maintenance, a very little

discouragement of labor owing to inefficient tools would more than overbalance any possible saving in cost. The list of tools required for the varied work of a track gang is quite large, and therefore an effort should be made to pare down the list as much as is practicable or safe, because it is correspondingly difficult for a track foreman to prevent losses due to carelessness. The following list is based on the requirements of a gang of six trackmen and a foreman.

A large proportion of the tools are for work on which not more than one or two men need work at any one time. When the list calls for six or more of any one tool, they are always the tools which are in constant or excessive use, or which are liable to become quickly broken, and of which an extra supply is a necessity for use while waiting for requisitions to make up for loss or breakage. The list is taken, with some slight modifications, from Camp's Notes on Track.

Adzes	2
Ax—chopping	1
Ax—hand	1
Auger, 2-inch	1
Bars—claw	2
" —crow	0
" —pinch	6
" —raising	1
" —tamping	8
Brace and bits	1
Brooms (coarse)	2
Brush hooks	2
Car—hand	1
" —push	1
Car chains	2
Chisels—cold	2
" —track	12
" —wood	1
Curving hooks	2
Chalk line	100 ft.
Ditch line	150 ft.
Drawshave	1
Dippers (or cups)	2
Files	3
Flags—red	4
" —green	2
Forks—ballast*	4
Gauge	1
Grindstone	1
Hammers—spike	4
" —sledge—16 lbs.	1
" —strike—10 lbs.	1
" —nail—claw	1
" —ballast*	6
Hatchet	1
Hoe—garden	1
Jack—track	1
Key—switch	1
Lanterns—white	2
" —red	2
" —green	2
Level board	1
" --spirit--pocket	1
Locks—switch—extra	2
Mattocks	2
Oil can—1 gal	1
" " —2 "	1
Oiler--squirt	1
Padlocks	2
Picks	8
" —tamping*	8
Punch—hand	1
Rake—garden	1
Rail drill	1
" " bits	6
Rule—two-foot	1
Scythes—grass	4
" —brush	4
Snaths	4
Shovels—track	8
" —scoop	4
" —long handle	1
Saw—hack, blades	12
" " frame	1
" hand	1
" crosscut	1
Screwdriver	1
Spade	1
Steel square	1
Tape (50′, graduated to tenths)	1
Tongs—rail	4
Tool box	1
Tool checks	6
Torpedoes (with box)	24
Verona spike puller	1
Vise	1
Water pail or jug	1
Weed scuffles	6
Wheelbarrows	3
Whetstones	4
Wire stretcher	1
Wrenches—track	3
" —monkey (8″)	1

* Needed only in stone ballast.

The first comment on the above list is in regard to the bars of various kinds. *Claw bars* are used for spike pulling. The ideal design is one that would permit pulling the spike with one stroke without changing the fulcrum, and that will also pull it clear out without bending. Apparently this is mechanically impossible and in spite of the many efforts which have been made and the new designs which have been brought out, the old "bull's foot" claw bar seems to be the best.

The "*Verona spike puller*" is attached to a spike which is in a confined place (such as behind a guard rail) and is operated by means of an ordinary claw bar resting on top of the rail.

"*Crow*" *bars* are considered to be those which taper down symmetrically to a wedge-shaped edge at the so-called "point," in contradistinction to "*pinch*" *bars* on which the chisel edge is even with (or outside of) the face line of the bar. The number of crow bars is put at "0" to emphasize Mr. Camp's opinion that the crow bar form should not be used and that the pinch bar form is far preferable.

Tamping bars should not weigh more than 10 pounds nor should they be more than 5 ft. 3 in. long. If the handle is solid it is rather small and hard to hold. It is therefore sometimes made as a pipe, with a malleable tamper. Another form uses a wooden handle.

Track chisels are cold chisels provided with a handle of wood by which they may be more readily and safely held in position. They should be about $1\frac{1}{8}$ in. square and 8 in. long, made of tool steel. A single blow may break them or render them useless until re-tempered and re-ground, and therefore a large number is necessary.

Gauges. These may be divided into three classes. The first is the "home-made" type of wooden gauge which is perhaps brass bound. One common objection to this form consists in the danger that it will not always be placed truly at right angles to the track. The effect of this error is to make tight gauge. To obviate this error, the "Huntington" track gauge has at one end two lugs about seven inches apart and one lug at the other end. The gauge is the distance from the single lug to the middle point of the seven-inch line, the two lines being at right angles. The device is theo-

retically perfect provided that the two lugs at the one end are both in contact with the head of the rail. A slight error in this respect will make the gauge too wide. The "Warren" gauge has two short circular arcs forming part of a complete circle, whose diameter is the gauge, fastened to the gauge bar.

Hammers. For section work, spike hammers should not weigh more than 8 pounds and have a length of about $10\frac{3}{4}$ inches. The 16-pound sledge is only needed for occasional very heavy work, when it is however almost essential. The 10-pound striking hammer is the better one to use with track chisels rather than to use the spiking hammers as is so frequently done. The ballast hammers are only used for breaking up stone for ballast and are unnecessary even for this purpose if machine broken ballast of uniform size is furnished.

Track jack. One of these is illustrated in Fig. 107. They are certainly handy and economical tools for the track gang, but more than one serious wreck has been caused by the inability of the gang to remove the jack before the arrival of an unexpected train, and as a derailing device a jack is exceptionally effective. Track instructions generally specify that they must not be placed between the rails.

Level board. Such a board usually has a level tube sunk in the upper edge. At one end a series of steps are cut, each with a base of about two inches, and with risers of one-half inch, beginning at the lower edge. The discussion on the superelevation of the outer rail (see § 119) shows the foolishness of over-refinement in such work. If the required superelevation is 2.5 in., the fifth step of the board may be placed on the outer rail and the plain end on the inner rail. When the track is properly adjusted the bubble should be in the center. Of course the adjustment of the level bubbles should be carefully watched and frequently adjusted if necessary.

Shovels. The best shovel for track work is the short handled shovel with square point, made out of a single piece of crucible steel. The blade should have a length of about 12 in. When this has been worn down to 9 in. it should be thrown away—for track work. Its use is then uneconomical. The scoop shovels are

for handling cinders and packed snow. The long-handled shovel is for digging post holes. It should be round-pointed.

The above list includes only the tools which will be required by almost any track gang. Cant-hooks and peavies are frequently necessary for handling timber. Blasting drills, wedges, powder and fuse are sometimes needed to break up masses of rock which may have fallen into a cut. Culverts and bridge channels get choked up with timber and debris of various kinds which may need ropes and tackle to clear them. A jim-crow rail bender is occasionally necessary, although one such may be made to serve two or more section gangs.

152. Work Trains. The work of a track gang is usually confined to one "section," which is usually not more than five miles long, and which on roads of the very heaviest traffic may be shortened up to a mile. On exceptionally poor light traffic roads, they are made eight and even ten miles. For ordinary work their hand car and push car furnish all needed transportation facilities for themselves and materials. But there is much work which is more irregular in its character, which must be handled on a larger scale, and which requires for economy a work train. Such work is the distribution of track materials such as ties, rails and ballast from the sources of supply to the places on the road where they are needed. Also, when re-ballasting is to be done on an extensive scale, when heavier rails are to be substituted throughout, or, in short, when there is any work to be done which is beyond the routine work of keeping the track up to its normal condition, then a work train with its usual force of laborers can accomplish the work with greater economy.

The work train is usually hauled by the worst engine on the road, sometimes by one which would otherwise be sent to the scrap heap. Whatever the justification of this policy, it may be carried so far that the regular train service suffers by the inability of the work train to keep out of the way of regular traffic, or else there is the false economy of wasting the time of the work train gang while trying to save by utilizing a worthless engine. A passenger engine which may have proved too light for regular service is preferable to a freight engine, since the work train should be capable of making good speed in running to a siding and the load is usually light.

The minimum requirements for the train should include a large caboose and a flat car provided with large tool boxes for picks, shovels, bars, hammers and other track tools. Underneath the caboose may be hung a large box in which may be stored ropes, pulley blocks, chains, jacks, etc. Since the cost of train crew wages, fuel, and other expenses which must be charged up for the use of the rolling stock will aggregate about $25 per day, there should be enough laborers attached to the train, and their work should be so planned as to justify this additional expenditure.

The minimum number of laborers should be about 20, and this should be increased to as many as can be profitably employed. Since the work of the train is scattered over a great distance, the company must choose between wasting considerable time both morning and evening while carrying the gang to and from their homes, together with many miles of train service, or of providing boarding cars, provided with bunks and one or two cars for kitchen and dining cars. One large, clean box car can be easily and cheaply fitted up as kitchen and dining car for 24 men. If the crew is much larger, one car should be devoted to kitchen and the storage of supplies and another car used for a dining car. An ordinary box car, or an old passenger car can be readily fitted up with four double lower berths and four double upper berths on one side and four lower and four upper single berths on the other side, thus accommodating 24 men. Even better accommodations may be provided when the need for such a train and gang is so regular that it will have practically permanent employment. A little extra money spent by the company in providing comforts for the men is immediately repaid in a better quality of work and less straggling off.

153. Ditching. While the routine clearing up of ditches is part of the work of a section gang, it will frequently happen, especially when the slopes have a disintegrating soil, and also when the slopes have been made originally too steep, that the winter's frosts will fill up the ditches to such an extent that it is best taken out with a work train gang. Ordinarily the section gang would need to load such material on their push car or on wheelbarrows and run the material out to the end of the cut where it may be harmlessly wasted. If the cut is very long, such hauling would

be very expensive. Since the regular schedule will not usually permit the train to stand long on the main track, especially on a single-track road, the loading must be done in the shortest possible time. This usually implies that a part of the gang should remain at the cut while the train is running off to unload and that they should all work there if the train must run to a siding merely to let a regular train pass. During such times the men can scrape down all loose material from the side slopes and loosen up the filling in the ditch, so that it is all ready for shovelling when the train arrives.

When the cuts are not very deep, such material is sometimes thrown up on the top of the bank, even by using a temporary staging on which the earth is thrown and then again shoveled to the top of the bank. In any such case the earth should be thrown well back from the edge of the bank so as to guard against its being again washed into the cut. It also should not interfere with the surface ditch which should have been cut on the top of the bank to prevent surface water from the slope above from running down into the cut.

154. Distributing Ties. The methods to be used necessarily vary with the sources of supply. If ties were obtainable from farmers and were delivered along the right-of-way on every section of the road, very little if any distribution by a work train would be necessary. When, as the other extreme, there is no local source of supply, the ties must be hauled many miles and so distributed that subsequent distribution by the trackmen will be reduced to a minimum. Since economy requires that ties shall only be replaced by an actual count of those which are defective, an essential preliminary is that a marker shall be placed along the the track for every ten ties required, or that the number required between two consecutive telegraph poles shall be marked on the poles so that it may be seen as the train approaches. By this means ties may be thrown off as required while the train is moving at a speed of about six miles per hour. On light traffic roads the work of tie distribution is frequently done by the local freight train. While this may be and often is the best policy, the cost per tie is much greater.

155. Distributing Rails. The method of handling rails depends very largely on the cars on which they are loaded, and also on their length. They are dropped off most easily when loaded on to flat cars, but frequently they are loaded on to gondolas and even in box cars by making a hole in the end of the car. Rails of 45 and 60 feet can only be loaded on to two consecutive flat cars. If they are being unloaded in one place simply for storage, a derrick of some kind, even though temporary, is wise economy. For distribution along the track they are either dropped over the side of the car or pulled off from the end. If they are dropped over the side they are apt to be kinked. Sometimes they are slid off on skids made of two timbers or pieces of rail about 10 feet long, but this is impracticable in some localities and it lands the rail at some distance from the track. The car to be immediately unloaded may be placed at the extreme rear of the train. Then a rail hook attached to a sufficient length of rope may be hooked into one of the bolt holes and the rail may be drawn off the end. By placing a "dolly" on the end of the car the rail may readily be drawn off by hand. As soon as the center of gravity passes the dolly, the outer end falls easily to the track and then, pulling the train ahead, the other end is let down easily as it drops off. Sixty-foot rails are so flexible that a considerable part of the length will be resting on the ground before the other end leaves the car, and will not be injured by dropping on the ties.

When the rails are especially long and heavy, an easier method is to hook on the rail-hook and attach the ropes to a track rail or around a tie. Then let the train move ahead until the rail is drawn off. Even the dolly under the rail at the end of the car is unnecessary with this method. If rails are needed for both sides, two such ropes and hooks may be used simultaneously. With a little more care this may be so done that the end of each rail comes almost exactly at the required joint, even allowing for staggering the joints on the two lines of rails. By attaching a push car to the car carrying the rails, the rails may pass over that and down on to the ground without any danger of injury from the drop.

The reverse operation—loading old rails onto a car—is heavy and costly work when done by hand. The best plan is to do it by means of a derrick. If it must be done without such aid, it facili-

tates the work to make an inclined plane by attaching a push car to the flat car on which the rails are to be loaded, and then by placing several dollies on this plane, the rails may run up on rollers with a minimum of actual lifting. It might be thought that a 70-lb, rail, 30 feet long, which weighs 700 pounds, should not be an excessive load for six men. When the men are carefully drilled to lift together and simultaneously raise the rail above their heads and throw it with machine-like precision on to the car, it may be (and is) successfully done in this way, but if one or two men shirk or do not lift with the others, the load is concentrated on the others. They successively become frightened and, to save themselves, "jump from under"; the remainder cannot sustain the load and it falls. It is lucky if someone does not have a foot crushed. The longer and heavier rails cannot be handled in this way.

156. Handling Ballast. A railroad must consider itself unfortunate if it does not have a gravel bank at some place along its line. The bank generally extends into the adjoining property, which is either bought outright or the gravel privilege is bought. The last method generally specifies that the top soil shall be reserved and spread upon the excavation after the gravel is exhausted. The gravel is usually overlaid with more or less vegetable soil. Sometimes the amount of this is so insignificant that its presence may be ignored, but if the depth is appreciable it will pay to strip it. A spur track whose minimum length is the length of the train must be run off from the main track. The method of attacking the bank depends on the method of digging—whether by steam shovel or by hand digging and shoveling.

About twenty cubic yards per day may be considered a fair day's work in loading gravel cars at the pit. A steam shovel with a dipper holding $1\frac{1}{2}$ to 2 cubic yards can load 800 to 1,200 cubic yards per day, depending on the prompt handling of the cars when loaded. Even this figure has been greatly increased under exceptionally favorable conditions. But the use of a steam shovel implies the use of a locomotive, which must be constantly at the pit shifting the cars so that there is a car constantly in place within range of the shovel. The cost of running such a shovel with its attendant locomotive will be about $50 per day. This will pay about 40 laborers who could dig about 800 cubic yards. Therefore, unless

the circumstances are so favorable that the shovel can exceed 800 cubic yards per day, the work may be done about as cheaply by hand shoveling. This is, however, about the limiting case. With good management a large shovel can take out gravel much cheaper than it can be done by hand. 20 cubic yards per day at a labor cost of $1.25 per day makes the gravel cost about six cents per cubic yard loaded on the car at the pit. The average cost of such hauling on a Western railroad was computed by the management to be 0.35 cent per cubic yard per mile. In this case the quantity handled was very large and the cost may be considered exceptionally low.

When the work is done on a small scale, and especially when the gravel is loaded by hand, hand methods would be used for unloading, but there is great economy in the use of a plow for unloading. This implies the use of flat cars, which are in fact almost universally used for ballast work—barring the special patented ballast cars. The plows are "center unloading" or "side unloading," and some of the most recent forms are adjustable so that they will unload all to either side or will unload to both sides in any desired proportion. The plow is drawn over the tops of the cars by a cable. The cheapest method is to stop the train where desired, set the brakes, uncouple the locomotive and attach to it a $1\frac{1}{4}''$ or $1\frac{1}{2}''$ wire cable. Commencing with the plow at the rear car the locomotive moves ahead and draws the plow over all the cars. This method has many objections, especially when it is done on curves. A much better method is to have a car carrying a hoisting engine, which may be supplied by steam from the locomotive by a flexible tube, if the car carrying it is placed immediately behind the locomotive, or preferably which is supplied from its own boiler placed on the car. A wire rope from this engine hauls the plow. One great advantage of this method lies in the fact that the train can be kept moving if desired while the plow is working.

If it is desired to distribute less ballast per car length than the car load, it may be done by moving the train ahead at just such a speed that will give the desired result. Incidentally, this method is very useful when making a fill from a trestle or to fill up a washout. By putting the plow at the rear of the train and drawing the plow backward, the speed of the train and of the plow can

be so regulated that the material will be deposited with as great concentration as desired. If it is desired to fill up a hole, the whole train load may be deposited in one spot by simply hauling the plow back as fast as the train moves forward. The average cost of thus unloading with a cable has been computed as about one-half cent per cubic yard. During recent years many styles of ballast cars which are easily and automatically unloaded have been placed on the market. Some of these have been designed with the distinct idea of being used in connection with local freight trains. They are picked up at the gravel pit by a local freight going in the desired direction, are hauled to places along the road which have been previously marked with stakes, are dumped with a delay of only a minute or so, then hauled on to where they may be side-tracked and hauled back to the pit by another local freight. Gondola and coal cars having hopper bottoms are also used extensively for hauling ballast.

157. Trestle Filling. This has become a very common form of work for the work train. When the construction of a railroad is once definitely decided and work is begun, any measure which will hasten the opening of the road for traffic has a very high money value. Therefore trestles have been built where embankments are a better form of permanent construction. The preliminary construction of trestles is further justified by the fact that the immediate construction of an embankment would often involve very expensive hauling with teams from borrow pits in the neighborhood, while a future fill may be made by the train load, as described below, at a much less cost. Incidentally, time is allowed to determine the maximum water flow through the hollow crossed by the line, and the size of the culvert required may be more accurately determined. The cost of the culvert, which may be very considerable, is also deferred to a time when the road can better afford it. At the time that many existing trestles were built the cost of timber in their localities was so small that the trestle may have been actually cheaper.

Many roads are now confronted by the necessity of either replacing the trestle or filling in with earth. While the relative cost is very variable, depending on the local price of timber, the proximity of a sufficient supply of available filling and the methods

to be employed, yet as an approximate figure it may be said that fills as high as 25 feet may be filled with earth as cheaply as a trestle can be reconstructed. But when it is considered in addition that the average amount of timber required annually for repairs of trestles is about one-eighth of the volume, also that the labor involved in maintenance is very great while it is almost insignificant on an embankment, also that the danger of accident on a trestle and the disastrous results of a derailment which may occur on a trestle is so much greater than on an embankment, the height at which it becomes economical to fill with earth instead of reconstructing the trestle increases until it may reach 50 feet. But the filling in of high trestles involves several special constructive features. The hollow may have at the bottom a very soft soil which cannot sustain a heavy embankment without considerable settlement. Such a settlement will prove destructive to almost any culvert unless a solid foundation may be made for it. Under such conditions a pile or concrete foundation for the culvert may become a necessity.

The dumping of earth and particularly of boulders, stumps and clods of frozen earth may do serious injury to the trestle unless means are taken to guard against it. This may be done by placing an "apron" on each side which will deflect the earth so that it falls outside the trestle. As the piles grow on each side the intermediate space will be filled up. The longitudinal braces which are most apt to suffer are sometimes strengthened by heavy timbers, which may be old stringers, etc. The filling should be done regularly along the length so that the bents will not be forced out of place by an unsupported pressure of earth on one side. If the bank is formed merely by dropping earth loosely from above, its slopes will be steeper than can be retained permanently. The result is frequently a disastrous slip. This feature justifies the spreading of the earth by scrapers as the filling proceeds. This method has the additional merit of packing the earth so that there is almost no settlement and the stringers may be pulled and the ballasted roadbed may be constructed very soon after the filling is complete. Otherwise the settlement is so great that six months or a year must elapse before track laying is permissible. During this time

the embankment may settle 10 per cent. This earth-spreading may be done for two or three cents per cubic yard.

The choice of filling material is an important matter. A sandy or gravelly soil is the best. Clay is apt to be very troublesome, for, no matter how hard it may be in dry weather, it will slip and run when it becomes wet. This is especially true when the base of a fill is on a steep side slope. In this case the whole fill may slide down the hill. One means of preventing this is to dig trenches along the slope. Even plowing the surface in contour furrows may be sufficient to prevent such a slip. The material for such a fill will usually come as the spoil from a widened cut, loaded perhaps with a steam shovel into dump cars or on to flats from which it is scraped by a plow, as previously described.

The practice of immediately planting tufts of Bermuda grass and even tree slips which will take root and grow and thus bind the embankment together as well as cover it with a surface of sod which will protect it from rain-wash is a measure of true economy which always pays. The total cost of such a fill must combine the cost of loading, hauling, spreading (if it is done) and the other expenses incidental to making a finished embankment, but the record made by many roads on these items show that it may be done at very much less cost than by the methods which are usual or possible during the original construction of the road.

158. Organization of Track Maintenance Labor. Although there is much variation in the practice of roads as to the succession of authority among the higher officials of the road, there is a very general agreement in placing the immediate supervision of the track for each division of approximately one hundred miles under a man known as roadmaster or perhaps supervisor. Some roads extend the authority of the roadmaster over a greater length of road and then appoint "supervisors" who individually control shorter lengths and who report to the roadmaster. The supervisor of each minor division superintends the work of the several section gangs in his division.

The roadmasters usually report to a division engineer, but except in matters of exceptional importance or which may involve new methods of work, the roadmaster is expected to do his routine work without special orders and to be responsible for its proper

execution. The roadmaster should be thoroughly conversant with every phase of the work done under him, and although it is preferable that he should have come up from the ranks, he should have a far better education than is possessed by the large majority of track laborers. The best roadmasters are those who have a technical education but who have served a sufficient time in the ranks to have become familiar with the practical details of track work. The Southern Pacific R. R. Co. require a roadmaster to "pass over the entire straight portion of his districts, either on foot or on velocipede cars, at least twice every month, and over that portion in canyons and in the mountains at least three times per month." He should have the work of the entire division so thoroughly mapped out in his mind that he has a sufficiently clear idea of the condition of every part of his division at any time and thereby save himself from censure due to any neglect of the track work at any place.

The most effective way to do this is to have the section foremen under such a state of drill that there will be no failure to remedy any slight defect or report a greater one. The roadmaster must rely on his discipline of the section foremen rather than on his personal observation, although he should not relax any effort to make his personal observations as thorough as possible.

The section foreman should generally be a man who has served his time as a track laborer, but he should also be a man who has sufficient education and intelligence to make out reports and correctly interpret plans and tabular statements. Another absolutely essential quality is an ability to control men without violence or abuse. He should not only thoroughly understand all the details of maintaining a track in condition, but should be able to repair a track and make it safe for trains in any ordinary emergency such as a broken rail, a washout, or a tearing up of the track due to a wreck. He should familiarize himself with all rules of the road regarding train running with which he may ever be immediately concerned, and also with all rules and standards of track construction which may have been adopted. The last qualification, which is becoming more and more essential, raises the standard for section foremen above what was formerly considered necessary.

Many roads require (by their rules) that the foreman shall take part in the manual labor of the gang. The wisdom of this rule depends somewhat on the work being done and on the number of men in the gang. If there are as many as eight laborers in the gang, the foreman may have all he can do in directing them. It is frequently advantageous to have the men work in pairs, and when the work is light, it may be best to have five laborers with the foreman in a gang, and then the foreman may work with the odd man.

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